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THE PHILIPPINE JOURNAL OF SCIENCE

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NEW OR LITTLE-KNOWN TIPULIDÆ FROM EASTERN ASIA (DIPTERA), XLVI

By CHARLES P. ALEXANDER
Amherst, Massachusetts *

FIVE PLATES

The species considered at this time are from various localities in southern Asia and derived from several sources. Collections from the western Himalayas, particularly from the Northwest Frontier Province of Pakistan and from Kashmir were taken by Dr. Fernand Schmid; from Nepal, in the east-central Himalayas, by Dr. Edward I. Coher and native assistants; from Ceylon, likewise secured by Dr. Schmid; and from Thailand, taken by Dr. Deed C. Thurman and Mrs. Thurman. Additional to these major series are a few others from other sources that are acknowledged in the text. I am very greatly indebted to my friends and colleagues who have added so materially to our knowledge of the Tipulidæ of this particularly rich and interesting part of Asia.

TIPULINÆ

DOLICHOPEZA (NESOPEZA) ANGUSTISSIMA sp. nov. **Plate 1, figs. 1, 5.**

Belongs to the *cuneata* group; general coloration of mesonotum cinnamon brown to darker brown, pleura patterned with light brown and yellow; antennæ short, black, pedicel abruptly light yellow; legs brown, tarsi white, basitarsi with a more or less distinct pale brown ring; wings subhyline, stigma dark

* Contribution No. 1292 from the entomological laboratory of the University of Massachusetts.

brown; cell 2nd A very long and narrow, with a secondary vein or thickening; male hypopygium with the posterior border of the tergite emarginate, with a small acute median spine; eighth sternite large, posterior border more narrowed and truncate.

Male.—Length, about 11 to 12 millimeters; wing, 10 to 11; antenna, about 2.4 to 2.6.

Female.—Length, about 12 to 13 millimeters; wing, 10 to 11; antenna, about 1.8 to 1.9.

Rostrum light yellow; palpi with first segment yellow, succeeding segments passing into brown. Antennæ relatively short, as shown by the measurements; scape dark brown, pedicel light yellow, flagellum medium brown: first flagellar segment longer than the succeeding two combined, the remainder short-cylindrical, terminal segment short. Head with front and anterior vertex light yellow, posterior part of head light chestnut; anterior vertex relatively broad.

Pronotal scutum light brown, the lateral ends yellow, posterior border and the scutellum light yellow. Mesonotal præscutum almost uniformly light brown to darker brown, the interspaces vaguely more testaceous; scutal lobes similarly light brown; posterior sclerites of notum more brownish testaceous, pleurotergite yellowed on ventral part. Pleura light brown, variegated with paler, especially on the dorsopleural region and posteriorly. Halteres elongate, dark brown, the base of stem restrictedly yellow. Legs with all coxæ and trochanters pale yellow; femora obscure yellow, narrowly clearer yellow basally, the tips dark brown; tibiæ brownish white, the extreme base clear white, tips narrowly more darkened; tarsi snowy white, the basitarsi a broad light brown ring on fore legs, more uniform but paler brown on mid-legs, still narrower and pale to virtually lacking on the posterior basitarsi. Wings (Plate 1, fig. 1) with a long basal petiole, anal region narrowed; subhyaline or faintly tinged with darker; stigma oval, dark brown, conspicuous; a vague darkening over anterior cord; veins dark brown. Venation: Rs of moderate length, subequal to R_{2+3}; cell M_1 about two and one-half times the length of its petiole; m-cu from one-third to about two-thirds its own length before the fork of M; cell 2nd A very narrow, the vein elongate; a secondary vein or thickening in the cell, as in *cuneata* and allies.

Abdominal tergites dark brown, with a pale spot or narrow band before midlength; sternites more uniformly yellowed, the

basal segments vaguely patterned with pale brown; hypopygium dark, the ninth segment more or less yellowed. Male hypopygium (Plate 1, fig. 5) small; tergite, *t*, with the posterior border conspicuously notched, with a small acute median spine, the broad lateral borders bent ventrad and cephalad into conspicuous blackened blades, their surface microscopically roughened. Outer dististyle, *d*, blackened, stoutest at base, narrowed to the obtuse tip; inner style oval in outline, beak narrow. Eighth sternite, *s*, extensive, blackened, narrowed posteriorly, the caudal border truncate, unarmed.

Habitat.—Thailand (Chiengmai).

Holotype, male, Dr. Buker's cabin, near Chiengmai, February 4, 1953 (*Thurman & Manop*). Allotopotype, female, pinned with type. Paratopotypes, several of both sexes. Paratypes, males and females, Doi Sutep, February 7 to 24, 1953 (*Thurman*).

Other members of the *cuneata* group include *Dolichopeza* (*Nesopeza*) *angusta* Edwards, of Malaya; *D.* (*N.*) *angustaxillaris* Alexander, of the Philippines; *D.* (*N.*) *annulitarsis* Alexander, Philippines; *D.* (*N.*) *bagobo* Alexander, Philippines; *D.* (*N.*) *bicornigera* Alexander, Philippines; *D.* (*N.*) *cinctitarsis* Alexander, Philippines; *D.* (*N.*) *cuneata* Edwards, Borneo; *D.* (*N.*) *inornatipes* Alexander, Philippines; *D.* (*N.*) *quadrifila* Alexander, Philippines; *D.* (*N.*) *ridibunda* Alexander, Philippines; *D.* (*N.*) *sandakanensis* Edwards, Borneo; and *D.* (*N.*) *subcuneata* Alexander, western Java. All of these numerous species differ from one another in the structure of the male hypopygium, particularly the ninth tergite and eighth sternite.

TIPULA (SCHUMMELIA) LAMA Alexander. **Plate 1, fig. 2.**

Tipula (*Schummelia*) *lama* ALEXANDER, Ann. Mag. Nat. Hist. XII 7 (1954) 593, 594.

The type, a male, was from Wat, Doi Sutep, Thailand, altitude 2,000 feet, January 18, 1953 (*Prayoon*).

Male.—Length, about 8.5 millimeters; wing, 9.5.

Size medium (wing of male 9.5 millimeters); general coloration of mesonotum brownish yellow, the præscutum with three faintly darker stripes, the broad central one farther split by a darker vitta; basal flagellar segments bicolored; wings (Plate 1, fig. 2) subhyaline, cells C and Sc slightly infuscated, stigma oval, darker brown; cell M_1 deep, about three times its petiole;

male hypopygium with the posterior border of the ninth tergite produced into a median setiferous blade or point; inner dististyle with the beak long and slender, without dorsal or posterior crests.

TIPULA (SCHUMMELIA) NOTOMELANIA Alexander. **Plate 1, figs. 3, 6.**

Tipula (*Schummelia*) *notomelania* ALEXANDER, Journ. N. Y. Ent. Soc. 71 (1958). In press.

Type, a male, from Bhainsi, Nepal, December 8, 1956 (*Coher*).

Male.—Length, about 9 millimeters; wing, 9; antenna, about 4.1.

Size small (wing of male 9 millimeters); mesonotum chiefly blackened, pleura transversely patterned with black and yellow; head with vertex darkened; femora yellow, tips narrowly blackened; wings (Plate 1, fig. 3) tinged with brown, restrictedly patterned with darker brown; m-cu at near midlength of M_{3+4}; abdominal tergites bicolored, obscure brownish yellow, the incisures darkened; male hypopygium (Plate 3, fig. 6) with the median area of tergite, *t*, produced into a flattened setiferous spatula; outer dististyle, *d*, broad.

TIPULA (TIPULODINA) FORFICULOIDES Alexander. **Plate 1, fig. 7.**

Tipula (*Tipulodina*) *forficuloides* ALEXANDER, Ann. Mag. Nat. Hist. XII 10 (1957) 104, 105.

The type, a male, was from the Walayar Forest, South Malabar, South India, altitude 1,000 feet, November 6, 1955 (*Susai Nathan*).

Male.—Length, about 17 millimeters; wing, 13; antenna, about 3.4; total length of spine of dististyle, 3.

Size relatively small (wing of male 13 millimeters); white bands on legs clear and distinct; costal field of wing blackened; male hypopygium (Plate 1, fig. 7) with the tergite, *t*, relatively small, the posterior border subtruncate, with the median area produced into a low lobe; lateral borders incurved, fringed with long conspicuous curved black setæ. Outer dististyle, *d*, small, its area slightly less than the outer basal lobe of the inner style, the outer margin near base a little expanded; inner style unusually small, as compared with its outer arm which is produced into a very long nearly straight rod, at near two-thirds the length narrowed into a gently curved acute spine; sensory area at base of arm; a single row of long setæ on face of arm as far as the narrowed apical spine; body of style small, only about

one-fourth as long as its outer arm; outer basal lobe darkened, obtuse, with a more or less distinct flange on posterior border.

TIPULA (TIPULODINA) MALABARENSIS sp. nov. **Plate 1, fig. 8.**

Belongs to the *venusta* group; size relatively large (wing of male over 18 millimeters); antennæ short; general coloration of mesonotum buffy, with three fulvous stripes that are conspicuously bordered by brown, the median vitta especially distinct; white tibial rings broad and conspicuous, tarsi patterned with white or greenish white; wings without darkening in cell M, apical darkened area solid; microtrichia of wing cells greatly reduced; male hypopygium with outer arm of inner style conspicuously bifid.

Male.—Length, about 23 millimeters; wing, 18.5; antenna, about 3.1.

Frontal prolongation of head yellow above, more darkened on sides; nasus long and slender, tipped with black; palpi dark brown, incisures narrowly paler. Antennæ of male short, as shown by the measurements; scape and pedicel yellow, flagellum black; flagellar segments subcylindrical or weakly enlarged basally; verticils of outer segments long. Front and anterior vertex yellow, posterior vertex light brown with a slender more blackened vertical tubercle, erect and directed slightly forward; head yellow beneath.

Pronotum yellow, the broad central area of the scutum dark brown, the sides vaguely darkened. Mesonotal præscutum with the restricted ground buffy, the disk with three narrow, more fulvous stripes that are bordered by darker, the intermediate pair with a common dark central line, the remaining borders paler; lateral præscutal borders behind the foveæ more brownish gray; scutal lobes extensively brown, continued across the midregion, restricting the pale ground to the suture and outer margins; scutellum yellow, the midregion and posterior border broadly darkened, parascutella dusky; mediotergite whitened, with two brown areas, confluent behind to include the posterior border. Pleura and pleurotergite pinkish white, virtually unpatterned; posterior dorsopleural membrane weakly darkened. Halteres dark brown. Legs with the coxæ and trochanters pinkish, with more or less distinct green reflections, the posterior coxæ restrictedly darkened at base; fore and middle femora light brown, tips rather narrowly black with a broader obscure white subterminal ring; tibiæ black, with a broad nearly

apical white ring, basitarsus chiefly black, with nearly the outer third white; second tarsal segment black basally, more greenish white at tip, outer tarsal segments more uniformly darkened; posterior femora brown, the subterminal pale ring very narrow and obscured, the dark tip correspondingly broader; tibiæ black, with two white rings, the outer broader and nearly terminal in position; basitarsus black, with nearly the outer half white; second segment white to greenish white, the base narrowly blackened; third tarsal segment greenish white, outer two segments brownish black, tinged with green; claws small. Wings virtually hyaline, restrictedly patterned with darker, including the blackened stigma and a small confluent seam over anterior cord, with a very narrow seam over the distal section of Cu_1; wing tip more extensively darkened, extending from the tip of cell R_2 into cell M_1, extensive and solidly darkened in cells R_3 and R_5; veins brownish black. Microtrichia of basal cells greatly reduced, lacking in cells before cord, 1st M_2 and bases of outer cells, except in the immediate vicinity of the veins. Venation: Cell 1st M_2 large, pointed at both ends; cell M_1 nearly twice its petiole; cell 2nd A narrow.

Abdominal tergites brown, basal rings paler, apices narrowly brownish black; basal sternites obscure yellow, the posterior borders vaguely darker, outer sternites more uniformly yellow; hypopygium large, chiefly yellow, the styli conspicuously blackened. Male hypopygium (Plate 1, fig. 8) with the tergite, *t*, transverse; posterior border truncate, on either side with a semicircular area of black hairs and short setæ, arranged about as in the figure. Outer dististyle, *d*, shown separately; pale, narrowed to the obtuse tip; inner style complex, the blackened beak short, outer basal lobe nearly as long but slender, provided with strong black setæ; outer arm of inner style distinctive, short and broad, divided into two strong spines, the outer one longer, fringed with long yellow setæ, inner spine in cases with a small point on outer margin before the acute apex. Gonapophysis appearing as a slender straight rod, near the tip with abundant setulæ. Ædeagus with an erect spine on either side before apex.

Habitat.—South India (South Malabar).

Holotype, male, Walayar Forest, altitude 1,000 feet, September 1956 (*Susai Nathan*).

The present fly and *Tipula* (*Tipulodina*) *xanthippe* Alexander are the only regional species of the subgenus that have the outer

arm of the inner dististyle of the hypopygium conspicuously forked. The two flies are quite different in the details of structure of the male hypopygia.

TIPULA (TIPULODINA) SUBSCIMITAR Alexander. **Plate 1, figs. 4, 9.**

Tipula (*Tipulodina*) *subscimitar* ALEXANDER, Journ. N. Y. Ent. Soc. 71 (1958). In press.

Type, a male, from Amlekhgang, Nepal, altitude 1,690 feet, August 26, 1956 (*Coher*).

Male.—Length, about 15 millimeters; wing, 12.5.

Belongs to the *pedata* group; size small (wing of male 12.5 millimeters); wings (Plate 1, fig. 4) whitish hyaline, the dark pattern restricted, especially the area in cell M; microtrichia lacking in cells at and beyond the arculus; basal section of R_{4+5} distinct, cell 2nd A narrow; male hypopygium (Plate 1, fig. 9) with the tergite, *t*, relatively long, slightly narrowed at outer end, apex broadly emarginate; on either side beneath with an incurved lobe, the outer margin with strong black setæ. Outer dististyle, *d*, very pale, slightly dilated on basal half; inner style with the disk high, beak obtuse, widely separated from the smaller lower beak; vestiture short, pale and inconspicuous; outer basal lobe cultrate, with conspicuous setæ; outer arm of inner dististyle a relatively long nearly straight spine that juts beyond the other hypopygial elements, the extreme tip acute, blackened, gently curved; sensory pits at base of outer arm, provided with very long setæ; a narrow row of pale bristles extends from the sensory pits virtually to the tip of the arm.

TIPULA (VESTIPLEX) GURKHA Alexander. **Plate 2, fig. 10.**

Tipula (*Vestiplex*) *gurkha* ALEXANDER, Journ. N. Y. Ent. Soc. 71 (1958). In press.

Types, including both sexes, Simbhanjang Pass, Nepal, altitude 8,190 feet, July 24, October 1 to 27, 1956 (*Coher*).

Male.—Length, about 12 to 13 millimeters; wing, 14 to 15; antenna, about 4.3 to 4.4.

Female.—Length, about 14 millimeters; wing, 15.

General coloration gray, the præscutum with four stripes that are margined with brownish black; basal flagellar segments bicolored; legs black, femoral bases obscure yellow; wings pale yellow, marbled with brown; abdomen yellow basally, the outer four segments black; male hypopygium (Plate 2, fig. 10) with the tergite, *t*, relatively small, completely divided at midline,

each lobe obtuse at tip; basistyle completely separated from the sternite by a suture, the outer apical angle produced into a flattened yellow plushlike blade that is farther extended into a slender black spine; ninth sternite, *s*, on either side adjoining the basistyle with a blackened knob that is produced into a long yellow spine, the acute tip black, directed dorsad and mesad; outer dististyle, *d*, a long blackened club, inner style with beak unusually slender; ædeagus subtriangular in outline, strongly narrowed outwardly; eighth sternite unarmed.

TIPULA (VESTIPLEX) LEPCHA Alexander. **Plate 2, fig. 11.**

Tipula (*Vestiplex*) *lepcha* ALEXANDER, Journ. N. Y. Ent. Soc. 71 (1958). In press.

Types, all males, Simbhanjang Pass, Nepal, altitude 8,190 feet, October 1, 1956 (*Coher*).

Male.—Length, about 18 millimeters; wing, 20; antenna, about 5.

Size large (wing of male 20 millimeters); general coloration of head and thorax gray, præscutum with four more blackish gray stripes, posterior sclerites of notum and the pleura yellowed; legs black, femoral bases yellowed; wings light brown, with restricted creamy areas; basal abdominal segments fulvous yellow, the outer four, including the hypopygium and appendages, black; male hypopygium (Plate 2, fig. 11) with the tergite, *t*, small, divided medially by pale membrane, the lobes obtuse at tips, with yellow setæ; basistyle, *b*, large, completely cut off from both tergite and sternite, the outer end farther separated from the body of style, thence produced caudad into a slender arm that is glabrous and polished at apex, farther prolonged into a slender spine that is directed mesad, the surface at base with very long yellow setæ; outer dististyle, *d*, blackened, expanded and slightly bidentate at tip, surface with sparse very small setæ; inner style distinctive, as shown, beak very slender; phallosome, *p*, distinctive, the very slender gonapophyses longer than the ædeagus, protruding caudad from the genital chamber, at base with a median acute compressed spine directed chiefly caudad.

TIPULA (INDOTIPULA) BLANDITA Alexander. **Plate 2, fig. 12.**

Tipula (*Indotipula*) *blandita* ALEXANDER, Ann. & Mag. Nat. Hist. XII 6 (1953) 902, 903.

The type male was from Doi Chom Cheng, Chiengmai Province, Thailand, altitude 3,000 feet, May 4 to 10, 1952 (*Thurman*).

Male.—Length, about 15 millimeters; wing, 16; antenna, about 5.

General coloration orange, the abdomen with a subterminal brownish black ring; antennæ with basal three segments pale, the remainder black, with very long verticils; wings subhyaline, the prearcular and costal regions more yellowed; male hypopygium (Plate 2, fig. 12) with the ninth tergite, *t*, narrowed posteriorly, produced into two relatively slender lobes, their tips obtuse, provided with strong incurved setæ at and near apex, some of these more flattened, notch a little narrower than the lobes but with nearly the same conformation; outer dististyle, *d*, relatively narrow, approximately four and one-half times as long as the greatest breadth, tip narrowly obtuse, setæ marginal and on outer fourth; inner style with the beak deep, cleaverlike, apex entire and very obtuse, lower beak slender, terminating in a blackened scabrous head, outer margin with a series of about fifteen flattened setæ, the innermost larger and stronger, outer basal lobe relatively narrow, with long twisted setæ at apex; gonapophysis a flattened pale blade, its apex a little more expanded.

TIPULA SHAWIANA Alexander. **Plate 2, fig. 13.**

Tipula shawiana ALEXANDER, Ann. Mag. Nat. Hist. XII 6 (1953) 750, 751.

The type male was from Doi Chom Cheng, near Doi Sutep, Thailand, altitude 3,000 feet, May 4 to 10, 1952 (*Thurman*).

Male.—Length, about 13 millimeters; wing, 16; antenna, about 5.

General coloration of thorax orange yellow, the præscutum with two narrow deeper orange intermediate stripes; vertex of head brownish gray with a barely indicated capillary darker vitta; femora and tibiæ brownish yellow, tarsi darker brown; wings with a weak brownish tinge, costal border light brown, stigma darker; abdomen yellow, the subterminal segments brownish black; male hypopygium (Plate 2, fig. 13) with the ninth tergite, *t*, large, virtually divided into two halves by median membrane, posterior border with a broad notch, lateral lobes obtuse, with setulæ and very small scattered setæ; basistyle separated from the sternite by a suture, its posterior end produced into a flattened blade, the tip obtuse; outer dististyle, *d*, a slender cylindrical rod with very long setæ, the longest nearly equal in length to the style; inner style with the beak

produced into a triangular point, the surface behind this with a group of long yellow outwardly directed setæ, lower beak obtuse, blackened, region of outer basal lobe produced, more or less bilobed, with short backwardly directed subspinous setæ; outer end of ædeagus, *a*, with a protecting flange, the apex above subtended by two needlelike spines, the lower margin with two slender rods; eighth sternite, *s*, with a very conspicuous depressed median lobe that is fringed with long setæ, the base on either side with smaller lobes and shoulders; setæ of outer fringe with microscopic swellings or enlargements of various sizes scattered over their length.

LIMONIINÆ

LIMONIINI

LIMONIA (LIMONIA) MICROPYGA Alexander. **Plate 2, fig. 14; Plate 3, fig. 25.**

Limonia (*Limonia*) *micropyga* ALEXANDER, Ann. Mag. Nat. Hist. XII 7 (1954) 595, 596.

Type male from Wat, Doi Sutep, Thailand, altitude 2,000 feet, January 18, 1953 (*Prayoon*).

Male.—Length, about 5 millimeters; wing, 5.6.

Size relatively small (wing of male 5.6 millimeters); mesonotum brown, pleura yellow, with a very conspicuous brownish black longitudinal stripe; rostrum blackened, narrowly pale above; antennæ black throughout; femora light brown; wings (Plate 2, fig. 14) with a brownish tinge, the oval stigma slightly darker brown, Sc long, cell 2nd A narrow; male hypopygium (Plate 3, fig. 25) with the ventromesal lobe of basistyle terminal in position; dististyle, *d*, a pale yellow blade, without basal enlargement, tip obtuse, setæ near tip very long.

LIMONIA (LIMONIA) PARVISTYLATA sp. nov.

Size small (wing of male about 4.5 millimeters); general coloration of mesonotum brownish yellow, darker medially, pleura yellow with a conspicuous brownish black longitudinal stripe; halteres infuscated; legs brownish yellow, the extreme tip of tibia and the tarsi white; wings with a dusky tinge, the oval stigma still darker; Sc_1 endng about opposite four-fifths the length of Rs, Sc_2 at its tip; male hypopygium with the ventral dististyle very small, its area only about one-fourth

that of the basistyle, rostral prolongation long and slender, with two short spines near outer end; gonapophysis erect, strongly darkened, broad-based, tapering outwardly to a short apical lobe.

Male.—Length, about 4 millimeters; wing, 4.6; antenna, about 1.0.

Rostrum brown; palpi black. Antennæ black throughout, relatively long for a member of this genus; flagellar segments passing from short-oval to more elongate, terminal segment longest, strongly pointed at outer end; verticils inconspicuous. Head dark brownish gray.

Cervical sclerites brownish black, pronotum paler. Mesonotal præscutum brownish yellow clearer yellow in front; posterior sclerites of notum darker brown especially medially, pleurotergite brownish yellow. Pleura with a broad conspicuous brownish black longitudinal stripe extending from the cervical region to the base of abdomen, passing just beneath the root of the halteres, the ventral pleurites and sternum clearer yellow. Halteres infuscated, especially the knobs. Legs with the coxæ and trochanters pale yellow, the fore coxæ slightly more infuscated; remainder of legs brownish yellow, the tips of the tibiæ and the tarsi paling to white; claws small, each with two slender spines close to base. Wings with a dusky tinge, the oval stigma still darker; veins brown. Venation: Sc relatively long, Sc_1 ending about opposite four-fifths the length of Rs, Sc_2 near its tip; free tip of Sc_2 pale, in approximate transverse alignment with R_2; cell 1st M_2 nearly as long as the distal section of M_3; m-cu at or close to the fork of M.

Abdomen brownish black, including the hypopygium. Male hypopygium with the tergite strongly narrowed outwardly, the apex produced into two low narrow lobes that are separated by pale membrane; setæ sparse, marginal, chiefly on the lobes. Basistyle with the ventromesal lobe large, obtuse. Dististyles two, very small, the outer style a gently curved blackened rod; ventral style oval, its area scarcely one-fourth that of the basistyle; rostral prolongation long and slender, arising from near midlength of the style, subacute at tip, with two small stubs or short blunt spines just back from the apex. Gonapophysis erect, strongly darkened, broad-based, tapering to a short narrow obtuse apical lobe.

Habitat.—Thailand (Chiengmai).

Holotype, male, Miss Lemmon's cabin, Doi Chom Cheng, altitude 3,000 feet, February 15, 1953 (*Thurman*).

The present fly differs from other small regional members of the subgenus in the white tarsi and in details of structure of the male hypopygium, especially the ventral dististyle and gonapophysis. The most similar of these species include *Limonia* (*Limonia*) *dravidica* Alexander and *L.* (*L.*) *perdocta* Alexander.

LIMONIA (LIMONIA) PERDOCTA Alexander. **Plate 2, fig. 15.**

Limonia (*Limonia*) *perdocta* ALEXANDER, Ann. Mag. Nat. Hist. XII 7 (1954) 594, 595.

The type was from Huey Pong, Lee District, Lampoon Province, Thailand, November 30, 1952 (*Thurman*).

Male.—Length, about 4.5 millimeters; wing, 5.

Size small (wing of male 5 millimeters); thoracic dorsum light brownish yellow, the præscutum with a conspicuous dark brown median stripe, pleura pale yellow; legs brownish black; wings (Plate 2, fig. 15) with a week brownish tinge, the stigma very slightly darker; Sc very long, cell 1st M_2 nearly square; male hypopygium with the ventral dististyle profoundly divided into two parts from an unusually small body.

LIMONIA (LIMONIA) SIELEDIVA sp. nov. **Plate 2, fig. 16, Plate 3, fig. 24.**

Size small (wing, about 5 millimeters); general coloration of præscutum obscure brownish yellow, with a dark median stripe, pleura dorsally with a brownish black longitudinal stripe, the ventral sclerites abruptly pale yellow; legs brown, the tips of the tibiæ and all tarsi yellowish white; wings with a faint brownish tinge, stigma darker; Sc long; male hypopygium with the ventral dististyle very small, rostral prolongation slender.

Male.—Length, about 5 millimeters; wing, 5; antenna, about 1.2.

Female.—Length, about 5 millimeters; wing, 5.

Rostrum dark brown; palpi black. Antennæ black throughout; flagellar segments oval, subequal to or a trifle shorter than the longest verticils; terminal segment elongate, more than one-half longer than the penultimate, the outer end strongly narrowed. Head brownish gray; anterior vertex narrow, especially so in the male.

Pronotum dark brown, paler behind. Mesonotal præscutum obscure brownish yellow, broadly darker brown medially, the lateral borders restrictedly darkened; scutal lobes brown, obscure yellow on midregion; scutellum testaceous yellow; postnotum

brown. Pleura pale yellow ventrally, the dorsal half, including the membrane, abruptly brownish black to form a broad longitudinal stripe from the head to the abdomen. Halteres brownish black, stem a little paler, its base narrowly yellow. Legs with the coxæ and trochanters whitened; femora brown, somewhat paler basally; tibiæ brown, the tips paling to obscure yellow; tarsi yellowish white, this color including all legs; claws of male slender, without armature except for very small spines at extreme base. Wings (Plate 2, fig. 16) with a faint brownish tinge, the oval stigma darker brown; veins brown. Venation: Sc long, Sc_1 about opposite two-thirds the length of Rs, Sc_2 near its tip; cell 1st M_2 rectangular (shorter in one wing of the type); m-cu variable in position, from before to beyond the fork of M.

Abdomen, including the hypopygium, dark brown. Ovipositor with the cerci small, slender, upcurved to the acute tips. Male hypopygium (Plate 3, fig. 24) with the tergite, *t*, broadest across base, strongly narrowed outwardly, the tip pale, truncate; entire surface of plate with abundant microscopic setulæ; a few strong setæ, chiefly at the apex. Sternite transverse, the posterior border very gently convex, with a single complete transverse row of strong setæ back from the border, with fewer other scattered bristles. Basistyle, *b*, with the ventromesal lobe large, simple. Dorsal dististyle, *d*, a flattened curved blade, widened beyond midlength, at apex narrowed into a straight spine; ventral style very small, its area only about one-half the ventromesal lobe of the basistyle, the oval body provided with relatively few but long setæ; rostral prolongation long, narrowed outwardly, at apex with one or two long setæ. Gonapophysis with mesal-apical lobe nearly erect, the short blackened apex obtuse. Ædeagus with the genital tubes widely separated.

Habitat.—Ceylon.

Holotype, male, Kandy, altitude 2,000 feet, January 14, 1954 (*Schmid*). Allotopotype, female.

The specific name, *sielediva*, is an ancient Indian name for Ceylon. The other small-sized regional species of *Limonia* that have whitened tarsi include *Limonia* (*Limonia*) *erichtho* Alexander, *L.* (*L.*) *latiflava* Alexander, and *L.* (*L.*) *parvistylata* sp. nov., all differing in details of coloration and details of the male hypopygium. The regional *Limonia longivena* (Edwards) is somewhat similar to the present fly, differing in

the coloration of the body and legs, with only the posterior tarsi whitened. I have never seen this fly but it evidently does not belong to *Thrypticomyia* Skuse where it originally was assigned by Edwards.

LIMONIA (LIMONIA) TAGAX Alexander. **Plate 2, fig. 17.**

Limonia (*Limonia*) *tagax* ALEXANDER, Ann. Mag. Nat. Hist. XII 7 (1954) 596, 597.

The type, a male, was from Doi Chom Cheng, Thailand, altitude 3,000 feet, January 2, 1953 (*Prayoon*).

Male.—Length, about 4 millimeters; wing, 4.5.

Size small (wing of male less than 5 millimeters); general coloration of thorax yellow, the pleura with a narrow dark brown longitudinal stripe; head gray, eyes long and narrow, contiguous above or virtually so; wings (Plate 2, fig. 17) subhyaline, the subcircular stigma brown; cell 1st M_2 open by the atrophy of basal section of vein M_3; male hypopygium with the dististyle relatively small, produced into a long, gently curved rostral prolongation.

LIMONIA (LIMONIA) VAJRA Alexander. **Plate 2, fig. 18; Plate 3, fig. 26.**

Limonia (*Limonia*) *vajra* ALEXANDER, Journ. N. Y. Ent. Soc. 71 (1958). In press.

The types were from Simbhanjang Pass, Nepal, altitude 8,190 feet, July 24 and October 1, 1956 (*Coher*).

Male.—Length, about 6.5 millimeters; wing, 7.5.

Female.—Length, about 7.5 millimeters; wing, 8.5

Size medium (wing of male 7.5 millimeters); mesonotal præscutum with three obscure yellow stripes; legs with femora brown or brownish yellow with a darker subterminal ring, tips yellow; wings (Plate 2, fig. 18) yellow, marbled with brown; Sc long, m-cu at or close to fork of M; male hypopygium (Plate 3, fig. 26) with the tergite, *t*, large, narrowed posteriorly, the caudal border gently emarginate; basistyle, *b*, large, the ventromesal lobe very large; dististyle, *d*, single, oval, narrowed into a long beak, the usual rostral spines very slender, hairlike; on outer margin of body of style at near midlength with a very compact group of about five spinelike setæ; gonapophysis, *g*, with mesal-apical lobe relatively short, darkened, terminating in a subacute point; ædeagus, *a*, broad, glabrous, the genital tubes lying close together at the midline, the tips produced slightly into short points.

LIMONIA (LIBNOTES) SUBAMATRIX sp. nov.

Belongs to the *amatrix* group; size small (wing of male 7 millimeters); general coloration of thorax yellow, with a narrow dorsal longitudinal stripe extending from the cervical region to the wingroot; legs black, tips of femora broadly and abruptly yellow, wings whitish, conspicuously patterned with brown, including almost complete bands beyond arculus, at cord, outer end of cell 1st M_2 and wing tip; darkened dots along veins very sparse or lacking; m-cu at near two-fifths the length of cell 1st M_2; vein 2nd A strongly curved.

Male.—Length, about 6 millimeters; wing, 7.

Rostrum and palpi black. Antennæ with scape black, pedicel yellow; flagellum broken. Front and narrow anterior vertex silvery white, posterior vertex medium brown, with a light gray stripe on either side of the narrower central ground line.

Pronotum greenish yellow. Mesonotum greenish yellow, the præscutum with two broad intermediate stripes of this color, separated by a capillary gray line; scutal lobes weakly darkened; posterior sclerites of notum and the pleura more yellowed, with a narrow dark brown line extending from the cervical sclerites across the dorsopleural membrane to the wing root. Halteres brownish black, base of stem narrowly yellow. Legs with coxæ and trochanters yellow; femora black, the tips broadly and abruptly light yellow; tibiæ and tarsi brownish black; claws four-toothed, outer spine longest. Wings whitish, conspicuously patterned with brown; posterior prearcular field and a spot above R_2 yellow; cell C uniformly darkened, Sc variegated by yellow before and beyond the origin of Rs; broad seams over cord, outer end of cell 1st M_2, and at ends of the veins, those in the costal region extended backward to form slightly broken or almost complete bands beyond arculus, at level of cord and fork of Sc, and at level of outer end of cell 1st M_2; outer half of cell R_2 darkened; the usual small spots on the veins virtually lacking, with only one or two on the distal section of M_{1+2}; veins yellowish, brown in the darker areas. Venation: Rs moderately arcuated; cell 1st M_2 long, with m-cu at near two-fifths its length; vein 2nd A strongly curved.

Abdomen, including hypopygium, yellow. Male hypopygium with the dorsal dististyle shorter and less sinuous than in *amatrix*.

Habitat.—Assam (Khasi States).

Holotype, male, Cherrapunji, Khasi Hills, altitude 4,000 feet, 1954 (*S. Sircar*).

The most similar regional species is *Limonia* (*Libnotes*) *thyestes* Alexander, of the Nilgiri Hills, South India, which differs in the large size, coloration of the legs and wings, and in the details of venation.

LIMONIA (LIBNOTES) NOTATA SICCA subsp. nov.

Male.—Wing, 13.5 millimeters.

Rostrum and palpi black. Antennæ with scape and pedicel black, flagellum yellow, outer segments more darkened. Head yellowish brown.

Pronotum obscure brownish yellow, more darkened on sides. Mesonotal præscutum with the disk light brown, the posterior half of midregion and the cephalic border gray, patterned with darker brown, including a line around the disk lying just inside the punctiform black pseudosutural foveæ; scutum and scutellum extensively pale yellowish white; mediotergite light gray, blackened laterally; pleurotergite light gray. Pleura more grayish yellow with two very narrow broken dark brown stripes, the more ventral one broadest across the base of the fore coxa where it includes more than the basal third, much narrower on the dorsal sternopleurite. Halteres pale yellow, apex of knob darkened. Fore legs black; remaining legs with the femora obscure yellow with a broad brownish black subterminal ring; all tarsi a trifle paler than the tibiæ; vestiture of fore legs reduced to abundant small spinelike setæ, of the other legs normal, this condition indicating that the broken type specimen is a male. Wing pattern and venation as in typical *notata,* m a little shorter.

Abdomen broken.

Habitat.—Assam (Khasi States).

Holotype, male, Cherrapunji, Khasi Hills, altitude 4,000 feet, 1954 (*S. Sircar*).

This fly differs from typical *Limonia* (*Libnotes*) *notata* (van der Wulp) in the coloration of the body and legs. In the latter character it likewise differs from the various allied species or races so far made known from the various Pacific islands.

LIMONIA (DICRANOMYIA) EMODI sp. nov.

Belongs to the *morio* group, allied to *nigrithorax;* legs brownish yellow; wings with the stigma distinct, brown; ventral

dististyle of male hypopygium with a single long rostral spine, ventral sclerite broad.

Male.—Length, about 5.5 millimeters; wing, 6.

Female.—Length, about 5 millimeters; wing, 5.5

Rostrum and palpi black. Antennæ black throughout; basal flagellar segments oval, the outer ones elongate, especially the terminal segment; verticils and setæ conspicuous. Head black, the anterior vertex not silvery as in various related species this appearance possibly due to discoloration.

Pronotum and mesonotum polished black, the restricted humeral region of the præscutum, posterior border of scutal lobes and the parascutella paler; scutellum and mediotergite slightly pruinose. Pleura black heavily silvery gray pruinose, especially on the dorsal sternopleurite, pteropleurite and meron. Halteres with stem yellow, knob brownish black. Legs with the fore coxæ darkened, remaining coxæ and all trochanters yellow; remainder of legs obscure brownish yellow, the outer tarsal segments darker. Wings tinged with brown, the prearcular and costal fields more brownish yellow; stigma oval, darker brown; veins brown, a trifle paler in the brightened fields. Venation: Sc_1 ending shortly beyond the origin of Rs, Sc_2 far retracted, Sc_1 alone about four-fifths as long as Rs; m–cu close to the fork of M.

Abdominal tergites brownish black, sternites paler; hypopygium brownish black. Male hypopygium with the tergite narrowly transverse, the cephalic border convex, the posterior margin produced into two long lobes that narrow gradually into blunt tips, separated by a notch that is approximately twice their own diameter. Basistyle relatively small, the ventromesal lobe slender, especially on outer half, the enlarged base with several strong setæ; at base of major lobe with a small tubercle tipped with about thirteen long setæ. Dorsal dististyle a gently curved rod, gradually narrowed into a short blackened apical spine; ventral style of moderate size, its area subequal to the total size of the basistyle, terminating in a very small slender beak; a single long rostral spine that is more than twice as long as the rostrum. Gonapophysis pale, the mesal-apical lobe relatively small, gently curved. Ninth sternite broader than long, its margin with about nine strong setæ on either side.

Habitat.—Kashmir.

Holotype, male, Muzaffarabad, altitude 3,250 feet, October 3, 1953 (*Schmid*). Allotopotype, female, pinned with type.

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The present fly is distinct from the only other regional member of the *morio* group, *Limonia* (*Dicranomyia*) *nigrithorax* (Brunetti), in the structure of the male hypopygium, as described by Brunetti.

LIMONIA (DICRANOMYIA) RUDRA sp. nov.

Size small (wing slightly over 5 millimeters); general coloration dark brownish gray; wings with a strong brownish tinge, with four still darker costal markings that alternate with obscure whitened areas; Sc_1 ending at near one-fourth the length of Rs, Sc_2 lacking; cell M_2 open by the atrophy of basal section of M_3; cell 2nd A broad.

Female.—Length, about 4.8 millimeters; wing, 5.2.

Rostrum and palpi black, the latter reduced. Antennæ with scape and pedicel black; flagellum broken. Head dark brown, sparsely pruinose, somewhat clearer on the anterior vertex and orbits; anterior vertex narrow.

Thoracic dorsum dark brown, pruinose, without distinct pattern. Pleura more evidently gray pruinose. Halteres with stem dirty white, knob dark brown. Legs with the coxæ dark gray; trochanters brown; femora brownish yellow, the tips narrowly dark brown; tibiæ and basitarsi paler, the tips narrowly infuscated; remaining tarsal segments dark brown. Wings with a strong brownish tinge, with four still darker costal markings that alternate with obscure whitened areas, the dark pattern being at arculus, two-thirds the length of vein Sc, Sc_1 and stigma; veins brown, slightly paler in the costal interspaces. Venation: Sc_1 ending shortly beyond the origin of Rs at near one-fourth the length of the vein, Sc_2 lacking; R_2 very faint, in transverse alignment with the free tip of Sc_2; cell M_2 open by the atrophy of basal section of M_3; m-cu a little longer than the distal section of Cu_1, close to the fork of M; cell 2nd A broad.

Abdomen dark brown, sparsely pruinose. Ovipositor with the cerci very slender, gently upcurved; hypovalvæ stout, blade-like.

Habitat.—Assam (Khasi States).

Holotype, female, Cherrapunji, Khasi Hills, altitude 4,000 feet, 1954 (*S. Sircar*).

Limonia (*Dicranomyia*) *rudra* is quite distinct from other Indian members of the subgenus that have cell M_2 of the wings

open, including *L.* (*D.*) *bhutanica* Alexander, *L.* (*D.*) *goana* Alexander, and *L.* (*D.*) *innocua* Alexander. All of these latter flies have the wings unpatterned or virtually so and with cell M_2 open by the atrophy of m instead of the basal section of M_3, as in the present fly.

LIMONIA (GERANOMYIA) GANESA sp. nov. **Plate 3, figs. 19, 27.**

Allied to *feuerborni;* general coloration of mesonotum brownish black, the lateral borders of the præscutum obscure yellow; rostrum moderately long, black; legs uniformly dark brown; wings tinged with dusky, stigma oval, darker brown; male hypopygium with the tergite narrow, transverse, the posterior border very gently emarginate; dorsal dististyle lacking; ventral style large and fleshy, the usual rostral spines fused to appear as a single unit.

Male.—Length, excluding rostrum, about 5.3 to 5.5 millimeters; wing, 6 to 6.2; rostrum, about 1.6 to 1.8

Rostrum relatively short, as shown by the measurements, black, the terminal filament pale. Antennæ black throughout, slightly more than one-half the rostrum; flagellar segments oval, with short verticils. Head dull brownish black, the narrow anterior vertex gray.

Cervical sclerites and pronotum brownish black. Mesonotal præscutum with the disk dark brown or brownish black, the humeral and lateral regions broadly obscure yellow; posterior sclerites of notum brownish black, sparsely pruinose, especially the central area of the scutum and postnotum. Pleura and pleurotergite chiefly yellow, the dorsal half broadly pale brown to form a diffuse stripe that farther involves the dorsopleural membrane; ventral sternopleurite weakly darkened. Halteres brownish black, base of stem narrowly yellow. Legs with the coxæ and trochanters light yellow; remainder of legs uniformly dark brown. Wings (Plate 3, fig. 19) rather strongly tinged with dusky, costal border still darker; stigma oval, darker brown; veins brown. Venation: Sc long, Sc_1 ending about opposite two-thirds to shortly before the fork of Rs, Sc_2 at its tip; cell 1st M_2 elongate, exceeding the distal section of vein M_{1+2} m-cu at or close to the fork of M.

Abdominal tergites and hypopygium dark brown, sternites obscure yellow. Male hypopygium (Plate 3, fig. 27) with the tergite, *t,* narrow, transverse, the posterior border very gently emarginate, the cephalic margin straight; each outer lateral

angle with a group of about 15 to 18 setæ of moderate length; surface of tergite with very abundant setulæ, those of the broad midsection larger than those of the triangular side pieces. Sternite with the setæ chiefly marginal, including a transverse outer row of four setæ. Basistyle, *b*, small ventromesal lobe simple. Dorsal dististyle lacking; ventral style, *d*, very large and fleshy, its area fully three to four times that of the basistyle; rostral prolongation stout basally, curved and narrowed to the tip, on outer margin at near midlength with a strong spine or pair of fused spines, the tips truncate. Gonapophysis, *g*, with mesal-apical lobe about as shown. Ædeagus broad, terminating in two broadly obtuse lobes; surface before apex with abundant delicate setulæ.

Habitat.—Nepal.

Holotype, male Amlekhgang, altitude 1,690 feet, September 24, 1956 (*Pratap Singh*). Paratopotypes, 4 males; paratype, of doubtful sex, Taubai, December 8, 1956 (*Coher*).

Although closely related to *Limonia* (*Geranomyia*) *feuerborni* Alexander, of Java and Sumatra, in the fundamental structure of the male hypopygium, as the loss of the dorsal dististyle, the present fly evidently is distinct in other details of the hypopygium, particularly the rostral prolongation, ædeagus and tergite. The specific name, *ganesa,* is that of the Hindu god of wisdom, represented as a short stout human with the head of an elephant.

HELIUS (HELIUS) EURYPHALLUS sp. nov.

Allied to *obliteratus;* mesonotal præscutum reddish brown with three dark brown stripes; head gray; antennæ of male relatively long, flagellar segments elongate, with a dense pale pubescence; legs brownish yellow, darker outwardly; wings whitish subhyaline, patterned with darker; basal section of vein R_{4+5} lacking, Rs, thus in longitudinal alignment with the outer section; basal abdominal segments bicolored, dark brown basally, their outer ends yellow, subterminal segments darkened to form a ring; male hypopygium with the dististyles terminal, outer style a very gently curved rod, its blackened apex microscopically toothed; inner style broad basally, the outer part strongly narrowed; ædeagus conspicuously expanded beyond base.

Male.—Length, including rostrum, about 6 millimeters; wing, 6.7; antanna, about 2.2.

Rostrum and palpi black, the former about as long as the remainder of head. Antennæ of male relatively long, as shown

by the measurements; scape dark brown, pedicel paler, first flagellar segment yellow basally, the remainder of organ brownish black; flagellar segments with a short dense pale pubescence but without distinct verticils. Head gray; anterior vertex narrow, about two-thirds the diameter of the scape.

Cervical region and pronotum weakly darkened, the latter more yellowed on sides. Mesonotal præscutum reddish brown with three dark brown stripes; scutal lobes dark brown, the central region pale, the color continued backward onto the base of the scutellum; remainder of scutellum and the mediotergite dark brown. Pleura and pleurotergite reddish brown. Halteres with stem yellow, knob darkened. Legs with coxæ and trochanters yellow; femora obscure yellow, vaguely more darkened just before apex; tibiæ and tarsi brownish yellow, the outer tarsal segments darker. Wings whitish subhyaline, patterned with darker, including the oval brown stigma; other spots and clouds at origin of Rs, cord, outer end of cell 1st M_2, outer ends of cells R_2 and R_3, and a still paler cloud at outer end of vein Cu; veins dark brown, paler in the prearcular field. Veins of outer half of wing with abundant macrotrichia. Venation: Sc_1 ending shortly beyond fork of Rs, Sc_2 at its tip; basal section of R_{4+5} lacking, Rs being in direct longitudinal alignment with R_{4+5}; veins R_{2+3} and R_{4+5} generally parallel to one another, diverging slightly toward their outer ends; cell 1st M_2 rectangular, shorter than vein M_4; m-cu about opposite r-m or nearly its own length beyond the fork of M.

Abdominal segments bicolored, yellow, broadly darkened basally and very narrowly so apically; subterminal segments brownish black to form a broad ring; hypopygium brownish yellow. Male hypopygium with the basistyle having a low setiferous lobe on mesal face near proximal end. Dististyles terminal; outer style a very gently curved rod, blackened at tip which is microscopically denticulate; inner style broad on basal half, strongly narrowed outwardly, at apex of the widened base with a concentration of short setæ. Gonapophyses or lateral arms appearing as slender gently curved rods. Ædeagus narrow at base, thence markedly expanded, the tip obliquely truncate.

Habitat.—Kashmir.

Holotype, male, Kar Gah, 1954 (*Schmid*).

Helius (*Helius*) *euryphallus* is quite distinct from all other regional members of the genus. In its general appearance it

is most like to the Japanese H. (*H.*) *obliteratus* Alexander, which has the structure of the male hypopygium quite distinct.

HELIUS (HELIUS) MURREENSIS sp. nov.

Size large (wing of female 8.5 millimeters); general coloration of notum dark brown, pleura concolorous, variegated with paler; wings weakly darkened, stigma and cell Sc slightly more infuscated; anterior branch of Rs not arcuated, basal section of R_{4+5} preserved; cell 1st M_2 rectangular, the second section of M_{1+2} nearly three times m.

Female.—Length, excluding rostrum, about 9 millimeters; wing, 8.5; rostrum, about 1.0.

Rostrum dark brown, relatively short, as shown by the measurements; palpi brownish black. Antennæ brownish black; scape elongate; proximal four flagellar segments short and crowded, transverse, the succeeding segments becoming elongate, with very long verticils, the longest nearly twice the segments. Head brownish black; anterior vertex moderately broad, about two and one-half times the diameter of the scape.

Pronotum brown, brightened posteriorly; pretergites pale yellow. Mesonotal præscutum chiefly dark brown, the humeral region vaguely brightened; posterior sclerites of notum chiefly dark brown, the posterior lateral angles of the mediotergite restrictedly obscure yellow; sides of scutellum and the parascutella pale. Pleura darkened dorsally, including the dorsopleural membrane, the sternopleurite more reddened; posterior pleurites more yellowed. Halteres with stem dusky, knob infuscated. Legs with the fore coxæ darker brown than the others; trochanters obscure yellow; remainder of legs, broken. Wings darkened, stigma and cell Sc very slightly more infuscated; veins brown. Venation: Anterior branch of Rs arcuated, as in *ferruginosus;* basal section of R_{4+5} preserved; cell 1st M_2 rectangular, the second section of M_{1+2} nearly three times m.

Abdominal tergites brown, the pleural membrane darker; sternites obscure brownish yellow, on the outer segments the posterior borders narrowly more darkened; genital shield dark brown; valves of ovipositor light horn color, darkened basally.

Habitat.—Pakistan.

Holotype, female, Murree Hills, altitude 7,242 feet, June 8, 1953 (*Schmid*).

The most similar regional species is *Helius* (*Helius*) *ferruginosus* (Brunetti), described from the Dawna Hills, Lower Burma. This has the body coloration much brighter and the details of venation distinct. A specimen in my collection determined by Brunetti as being *ferruginosus*, from the Darjeeling District in the eastern Himalayas is not correctly identified and is closer to the present fly, yet apparently distinct.

ANTOCHA (ANTOCHA) LIBITINA sp. nov.

Size medium (wing 7 millimeters or more); thorax and abdomen gray, the præscutum with three confluent brown stripes; legs brownish black, femoral bases restrictedly brightened; wings with a dusky tinge, stigma scarcely evident; male hypopygium with the lateral tergal lobes distinct; outer dististyle microscopically toothed at tip; inner apophysis extended into an acute point.

Male.—Length, about 7 to 7.5 millimeters; wing, 7 to 7.5; antenna, about 1.0 to 1.2.

Female.—Length, about 7.5 to 8.5 millimeters; wing, 8 to 9.

Rostrum and palpi black. Antennæ black, scape pruinose; flagellar segments oval. Head brownish gray, the broad posterior vertex darker brown.

Pronotum brown above, gray on sides. Mesonotal præscutum with the disk occupied by three confluent brown stripes, the lateral borders gray; scutal lobes brown; posterior sclerites of notum and the pleura gray; dorsopleural membrane dark. Halteres with stem yellowed, knob infuscated. Legs with coxæ and trochanters gray; remainder of legs dark brown or brownish black, the femoral bases restrictedly brightened; claws of male with a single relatively short tooth. Wings with a dusky tinge, the stigmal region not or only vaguely indicated; veins brown. Venation: m–cu variable in position, from at to shortly before the fork of M.

Abdomen dark gray, including the hypopygium. Cerci smooth. Male hypopygium with the tergite transverse; lateral lobes low and obtuse, the broad central area truncated. Basistyle short and stout. Dististyles apical in position, both long and gently arcuated; outer style sclerotized, especially outwardly, the apex microscopically toothed; inner style a little broader, its apex obtusely rounded. Lateral gonapophysis a flattened paddlelike blade, inner apophysis a little more elongate, a narrow blade that is extended into a slender spine.

Habitat.—North Afghanistan (Hindukush Range).

Holotype, male, Qualatak, Salang Valley, altitude 1,950 meters, October 5, 1952 (*Klapperich*). Allotopotype, female, pinned with the type. Paratopotypes, of both sexes, with the types, altitude 1,950 to 2,050 meters, October 5 to 11, 1952. Paratypes, of both sexes, Andarab Valley, altitude 1,240 meters, September 25, 1952; Femsch-Tagani, Kinjan Valley, altitude 2,100 meters, October 4, 1952; Ejan, Salang Valley, altitude 2,050 meters, October 11, 1952 (*Klapperich*).

Antocha (*Antocha*) *libitina* is quite distinct from other regional species in the coloration and in the structure of the male hypopygium. The flies were found associated in nature with the even larger *A.* (*A.*) *nebulipennis* Alexander which is well distinguished by the patterned wings. An important paper by the collector concerning his expedition to Afghanistan should be consulted.[1]

ANTOCHA (ANTOCHA) PERSTUDIOSA Alexander. **Plate 3, figs. 21, 28.**

Antocha (*Antocha*) *perstudiosa* ALEXANDER, Journ. N. Y. Ent. Soc. 71 (1958). In press.

The types were from Taubai, Nepal, December 8, 1956 (*Coher*).

Male.—Length, about 3.5 millimeters; wing, 4; antenna, about 0.7.

Close to *studiosa* Alexander, of South India; mesonotum patterned with brown, in cases extensively so; antennal flagellum dark brown; wings (Plate 3, fig. 21) whitish, stigma brown; male hypopygium (Plate 3, fig. 28) with the dististyles, *d*, slightly subterminal; outer style glabrous, unequally bifid at apex, both points obtuse, the lower one longer; inner style a little longer, narrowed to the obtuse tip, provided with strong setæ; phallosome, *p*, conspicuous; outer gonapophyses appearing as long-oval pale blades, inner apophyses long, slightly sinuous, the outer end very slender, bent at a right angle: ædeagus slender.

ORIMARGA (ORIMARGA) SHERPA Alexander. **Plate 3, fig. 20.**

Orimarga (*Orimarga*) *sherpa* ALEXANDER, Journ. N.Y. Ent. Soc. 71 (1958). In press.

The unique female type was from Amlekhgang, Nepal, altitude 1,690 feet, September 19, 1956 (*Coher*).

[1] Klapperich, J. Auf Forschungsreisen in Afghanistan. Entomologische Blätter 50 (1954) 109–118, complete list of stations, map.

Female.—Length, about 5 millimeters; wing, 4.6.

General coloration of mesonotum light brown, the lateral borders and the pleura more yellowed; antennæ black; legs brown; wings (Plate 3, fig. 20) very weakly tinged with brown; r-m lying some distance beyond the level of R_2, the latter about two-thirds as long as R_{1+2}; M_{3+4} longer than M_4.

PEDICIA (TRICYPHONA) BUETIGERI sp. nov.

General coloration of thorax light brownish gray, præscutum with three brown stripes, pleura buffy; antennæ 15-segmented, black; wings with cell 1st M_2 closed, small; outer four abdominal segments, including the hypopygium, brownish black; male hypopygium with the lateral tergal arms incurved at tips; dististyle small, suboval; phallosome with the apophyses appearing as small slender rods.

Male.—Length, about 6.5 millimeters; wing, 7.

Rostrum plumbeous; palpi black. Antennæ 15-segmented, black, scape pruinose; basal flagellar segments subglobular, short and crowded, outer segments passing into oval, shorter than the verticils. Head light gray; anterior vertex broad.

Pronotal scutum dark brown, scutellum paler. Mesonotal præscutum light brownish gray, with three brown stripes, the central one broad, slightly divided behind, lateral stripes more pruinose; scutal lobes brownish gray, central area and the scutellum more testaceous; postnotum brownish testaceous to buffy. Pleura buffy. Halteres with stem pale, knob weakly infuscated. Legs with the coxæ brownish yellow; trochanters yellow; femora brownish yellow basally, passing into brown at outer ends; tibiæ and basitarsi light brown, tips narrowly darker, remainder of tarsi dark brown to black. Wings weakly suffused, prearcular and costal fields more yellowed; stigma small, pale brown; veins medium brown. Venation: Cell R_4 petiolate by a relatively long R_{4+5}, this subequal to r-m which is placed shortly beyond the origin; cell 1st M_2 small, M_{3+4} shorter than M_4; cell M_1 present; m-cu at or just beyond the fork of M.

Abdominal tergites brown, basal sternites slightly paler; outer four segments brownish black. Male hypopygium with the lateral tergal arms conspicuous, straight, the short tips incurved; median region of tergite produced, its border subtruncate to very feebly convex. Basistyle without apical lobes. Dististyle apparently single but bilobed, appearing as a small

suboval lobe at apex of the basistyle, set with abundant short black spinules, the lower margin produced into a short triangular darkened beak. Phallosome broadly transverse, the apophyses appearing as small slender rods.

Habitat.—Pakistan (Northwest Frontier Province).

Holotype, male, Surgun sur, altitude 6,875 feet, July 29, 1953 (*Schmid*).

Named for Mr. J. J. Büetiger, associated with Dr. Fernand Schmid in the Mission Zoologique Suisse au Cashemire in 1953–54. Most similar to species such as *Pedicia* (*Tricyphona*) *insulana* (Alexander), *P.* (*T.*) *schummeli* (Edwards) and *P.* (*T.*) *unicolor* (Schummel), differing in the coloration, venation, and especially in the structure of the male hypopygium, particularly the tergal lobes, dististyle, and gonapophyses.

DICRANOTA (DICRANOTA) LONGISECTOR sp. nov.

Size large (wing 8 millimeters or more); antennæ of male elongate; general coloration gray, præscutum with four brown stripes, the intermediate pair narrowly separated; wings faintly patterned with darker; Rs unusually long, approximately four or five times the relatively long R_{2+3+4}; cell M_1 present; male hypopygium with the interbase a simple blade, its tip microscopically scabrous.

Male.—Length, about 8 to 9 millimeters; wing, 8 to 10; antenna, about 3.5 to 3.8.

Female.—Length, about 8 to 8.5 millimeters; wing, 10 to 11.

Rostrum very short, yellow; palpi beyond basal segment light brown. Antennæ of male elongate, black; flagellar segments long, with sparse short verticils and a dense erect pubescense. Head light gray, the center of the posterior vertex infuscated, with a capillary still darker vitta; anterior vertex narrowed, projecting between the antennal bases.

Pronotum gray, broadly infuscated medially. Mesonotal præscutum light gray, with four brown stripes, the intermediate pair separated by a capillary ground line; posterior sclerites of notum light gray, each scutal lobe with two brown areas; parascutella darkened behind. Pleura and pleurotergite gray; posterior part of propleura more yellowed forming a transverse area; sclerites at the wing base pale. Halteres weakly infuscated, base of stem yellow. Legs with coxæ pale,

pruinose; trochanters yellow; femora and tibiæ brownish yellow to light brown, the tips narrowly darkened; tarsi passing through brown to brownish black. Wings subhyaline, stigma and very vague cloudings at origin of Rs and over the cord pale brown; veins brown. Venation: Sc_1 ending about opposite the supernumerary crossvein in cell R_1; Rs unusually long, approximately four to five times R_{2+3+4}; cell M_2 open; cell M_1 small; m-cu from about one-third to one-half its length beyond the fork of M.

Abdomen of male much lighter and brighter than in female, tergites brown with broad yellow lateral and posterior borders, sternites almost uniformly yellow; in female, tergites gray with a broad continuous brown median stripe, sternites very vaguely patterned with pale brown. Male hypopygium with the tergite large, subquadrate, the posterior border very gently concave, the lateral angles slightly produced. Basistyle with the apical lobe low and rounded; interbase a simple curved yellow blade, slender, gently curved to the narrowly obtuse tip, the surface of the latter microscopically roughened or scabrous. Two simple dististyles, one shorter and broader, provided with long pale setæ; second style with scattered small setigerous punctures, the setæ at the base longer and more delicate. Phallosome compact, the gonapophyses a little broader than the decurved ædeagus.

Habitat.—Kashmir.

Holotype, male, Skardu, altitude 7,600 feet, October 4, 1953 (*Schmid*). Allotopotype, female, pinned with the type. Paratopotypes, males and females, altitude 7,550 to 7,600 feet, October 4 to 13, 1953 (*Schmid*).

Readily distinguished from other members of the typical subgenus, as *Dicranota* (*Dicranota*) *bimaculata* Schummel and *D.* (*D.*) *guerini* Zetterstedt, by the unusually long Rs and in the details of structure of the male hypopygium.

DICRANOTA (RHAPHIDOLABIS) FURCISTYLA Alexander. **Plate 3, figs. 23, 29.**

Dicranota (*Rhaphidolabis*) *furcistyla* ALEXANDER, Ann. Mag. Nat. Hist. XII 7 (1954) 597, 598.

The type, a male, was from Doi Chom Cheng, Thailand, altitude 3,000 feet, January 2, 1953 (*Prayoon*).

Male.—Length, about 3.5 millimeters; wings, 4.2.

Size relatively small (wing of male 4.2 millimeters); mesonotal præscutum obscure yellow, the disk with three dark brown

stripes; antennæ relatively long; legs light brown; wings (Plate 3, fig. 23) subhyaline, stigma vaguely indicated, R_{2+3+4} long, Anal cells narrow; male hypopygium (Plate 3, fig. 29) with the posterior border of tergite, *t*, produced into a broad lobe, the apex truncate, with several long setæ; basistyle on outer face produced into a tubercle; interbase a powerful rod that narrows into an elongate blade; dististyle, *d*, forked, the outer arm smaller, microscopically tuberculate and provided with delicate setulæ, inner arm longer, terminating in two strong setæ; a strong pale spine on outer margin of basistyle, *b*, at base of the dististyle.

DICRANOTA (RHAPHIDOLABIS) HOPLOMERA sp. nov.

General coloration of thorax reddish brown, præscutum with poorly indicated darker stripes; antennæ 15-segmented, black throughout; wings subhyaline, stigma very faintly indicated; R_{2+3+4} preserved, a little longer than the basal section of R_5; male hypopygium with the tergite unarmed; apical lobe of basistyle low and rounded, set with abundant blackened spicules; interbase large, deeply forked at near midlength; outer dististyle very small, inner style much larger, scoop-shaped.

Male.—Length, about 4 to 5.5 millimeters; wing, 4.5 to 6.5.

Female.—Length, about 6 millimeters; wing, 6.5.

Rostrum testaceous or light brown; palpi darker. Antennæ 15-segmented, dark brown, short in both sexes; flagellar segments oval. Head light gray.

Pronotum light brown. Mesonotal præscutum reddish brown, sparsely pruinose, with a pair of dark brown intermediate stripes that are confluent in front; scutal lobes brown, the central region and the parascutella yellow; posterior sclerites of notum brownish yellow, sparsely pruinose. Pleura yellowish brown; dorsopleural membrane yellowed. Halteres with stem yellow; knob large, infuscated. Legs with all coxæ and trochanters yellow; remainder of legs brownish yellow, the outer tarsal segments blackened. Wings subhyaline, stigma very faintly indicated; veins brown. Venation: Sc long, Sc_1 ending beyond the fork of R_{2+3+4}, the latter short, a little longer than the basal section of R_5; Rs varying from nearly straight to weakly angulated and spurred before midlength; m-cu before midlength of M_{3+4}; cell M_3 very variable in size, in the type subequal to cell M_1, in some paratypes much larger, as is normal in the subgenus.

Abdomen brown, hypopygium more yellowish brown. Male hypopygium large; tergite simple, posterior border subtruncate or feebly convex with scarcely indicated lateral angles. Basistyle with the apical lobe low and rounded, obtuse, densely set with microscopic black spicules; interbase distinctive, large, at near midlength deeply forked, one blade narrow, simple, the other bearing a lateral tooth before the slender apical spine. Outer dististyle very small, with long setæ on outer half; inner style much larger, scoop-shaped, with a more or less distinct tooth or flange on the inner margin at near one-third the length. Phallosome with the gonapophyses closely appressed to the ædeagus.

Habitat.—Pakistan (Northwest Frontier Province).

Holotype, male, Besal, altitude 10,715 feet, July 8, 1953 (*Schmid*).

Allotopotype, female, altitude 10,760 feet, June 25, 1953. Paratopotypes, males, with the allotype; paratypes, males, Valle de Barthe, July 28, 1953; male, Teru, altitude 10,200 feet, September 15, 1954 (*Schmid*).

Readily distinguished from all other Himalayan species of *Rhaphidolabis* by the structure of the male hypopygium, particularly the dististyles and interbase. There is an unusual range in body coloration and venation shown in the series on hand but all have the same hypopygial structure and evidently are conspecific.

DICRANOTA (RHAPHIDOLABIS) OBESISTYLA sp. nov.

General coloration of thorax light gray, præscutum with a slightly darker central stripe; wings subhyaline, stigma slightly darker; R_{2+3+4} present; male hypopygium with the posterior border of the tergite trilobed; basistyle with a pencil of long setæ on mesal face near apex; interbase a narrow rod, twisted near apex; outer dististyle and apical lobe of basistyle with spinelike blackened setæ; inner dististyle very broad, with a small accessory axillary lobule; gonapophysis broad, bilobed at tip.

Male.—Length, about 5 to 6 millimeters; wing, 5.5 to 6.5.

Female.—Length, about 6 millimeters; wing, 6.

Rostrum and mouthparts yellow; palpi brownish black. Antennæ 13-segmented, short, black, scape a little paler basally; flagellar segments oval, beyond the first with short verticils. Head light gray.

Pronotum weakly darkened and pruinose above, more yellowed laterally and behind. Mesonotal præscutum light gray, with a slightly darker central stripe, the usual lateral stripes much paler, more yellowed; scutal lobes reddish brown, the central area and posterior sclerites pale, more or less pruinose. Pleura and pleurotergite yellow or buffy, sparsely pruinose. Halteres with stem pale yellow, knob infuscated. Legs with coxæ and trochanters yellow; femora yellow, slightly darker at tips; tibiæ and tarsi brownish yellow, the outer segments pale brown. Wings variable in shape, at high altitudes (Lal Pani) much narrower; subhyaline, stigma slightly darker; veins brown. Venation very variable; Sc_1 ending beyond fork of R_{2+3+4}, in cases the latter reduced or lacking; Rs short, feebly arcuated to more strongly arcuated or angulated at near midlength; R_2 commonly close to tip of R_1; R_{2+3+4} about three times the basal section of R_5, in cases the latter very reduced; m-cu variable in position, from about one-third to nearly its own length beyond the fork of M.

Abdomen brown, subterminal segments darker, basal sternites and hypopygium paler. Male hypopygium with the posterior border of tergite conspicuously trilobed, the lateral angles produced into slender points, the median region with a shorter usually narrow lobe, its tip with long setæ. Basistyle with apical lobe relatively small, with several strong spinelike setæ; mesal face of style near apex with a group of eight or nine very long setæ forming a loose pencil; interbase a long slender yellow rod, the apical third slightly twisted and flattened into a narrow blade, the tip acute. Outer dististyle an oval lobe, its apical third with numerous strong spinelike setæ; inner style subequal in length but broader, mitten-shaped, having a smaller axillary lobule at base, tip of major style narrowed, with sparse setæ. Phallosome with the gonapophyses very broad, narrowed to an obtuse apical beak, with a small lateral shoulder that is microscopically setulose; ædeagus a blackened rod that terminates in an obtuse head.

Habitat.—Kashmir and Pakistan (Northwest Frontier Province).

Holotype, male, Besal, Pakistan, altitude 10,715 feet, July 10, 1953 (*Schmid*). Allotype, female, Kel, Kashmir, altitude 6,544 feet, May 19, 1954 (*Schmid*). Paratopotypes, males, June 25 to July 10, 1953; paratypes, males, Lal Pani, Pakistan, altitude 12,000 feet, September 5, 1953; Surgun sur, Pakistan,

altitude 6,875 feet, June 29, 1953; Kel, Kashmir, with the allotype, May 19, 1954; Minimarg, Kashmir, September 10, 1953 (*Schmid*).

Readily distinguished from all other Himalayan members of the subgenus by the structure of the male hypopygium, particularly the tergite, basistyle and phallosome.

DICRANOTA (RHAPHIDOLABIS) TUMIDOSA sp. nov.

Size medium (wing 6 millimeters or less); general coloration gray, the præscutum with three brown stripes; antennæ short, brownish black; wings subhyaline, stigma pale brown; Rs commonly angulated or slightly spurred, R_{2+3+4} present; male hypopygium with the posterior border of tergite having a low truncate median lobe, the dorsal surface back from the margin with a further large rounded lobe; outer dististyle oval, its outer half with strong black setæ, inner style at apex expanded a triangular blade.

Male.—Length, about 4.5 to 5 millimeters; wing, 5.5 to 6; antenna, about 0.9 to 1.0.

Rostrum brown; palpi brownish black. Antennæ short, brownish black; flagellar segments short-oval to oval, verticils much shorter than the segments. Head above brownish gray, the orbits narrowly light gray.

Pronotum brownish gray. Mesonotum gray, the præscutum with three clearly defined brown stripes; posterior sclerites gray, the centers of the scutal lobes brownish gray, parascutella yellowish brown. Pleura gray; dorsopleural membrane buffy. Halteres with stem dirty white, clearer at base, knob infuscated. Legs with fore and middle coxæ gray pruinose, posterior pair more yellowed; trochanters yellow; femora light brown, somewhat darker outwardly; tibiæ and tarsi brown to dark brown. Wings subhyaline, base more yellowed; stigma very pale brown, ill-delimited; veins pale brown, more yellowed at wing base. Venation: Sc_1 ending about opposite fork of R_{2+3+4}; Rs varying from nearly straight to angulated and spurred at near midlength; R_{2+3+4} variable in length, from just longer than the basal section of R_5 to almost twice this length.

Abdomen dark brown, subterminal segments still darker to form a ring; hypopygium yellowish brown to light brown. Male hypopygium with the posterior border of tergite produced into rounded lobes on the sides, the extensive central area with

a much broader lobe, its truncated border fringed with strong setæ; dorsal surface of tergite back from the border with a dark rounded lobe, the surface with a few small setæ only. Basistyle with a small and inconspicous lobule at apex on inner face, tipped with long setæ; mesal face of style at near midlength with a concentration of strong black setæ, some of which are longer and more slender; interbase a strong simple rod, its base dilated, the apex less evidently expanded. Outer dististyle a large oval lobe, the outer half set with strong black setæ; inner style large, beyong the base expanded into a triangular blade, the outer apical angle obtuse. Phallosome with the gonapophyses shorter but broader than the slender ædeagus, the tip of the latter slightly curved.

Habitat.—Kashmir and Pakistan.

Holotype, male, Khoghozi, Hindukush Range, Chitral, Pakistan, altitude 5,180 feet, October 15, 1954 (*Schmid*). Paratopotypes 2 males, October 5, 1954; paratype, male, Darkot, Kashmir, altitude 8,900 feet, August 17, 1954 (*Schmid*).

In its general appearance the present fly is most like to *Dicranota* (*Rhaphidolabis*) *sordida* (Brunetti) and *D.* (*R.*) *subsordida* Alexander, differing conspicuously in the structure of the male hypopygium, particularly the tergite, interbase and dististyles.

DICRANOTA (RHAPHIDOLABINA) SUBSPECTRALIS sp. nov. **Plate 3, fig. 22.**

General coloration of mesothorax whitish or whitish gray, slightly darker posteriorly, mesonotum very high and gibbous; legs white, the tips of the femora very narrowly black, of the tibiæ scarcely darkened; wings whitish subhyaline, with a restricted dark pattern, best indicated by a deepening in the color of the veins; R_{2+3+4} present, subequal to the basal section of R_5; R_{1+2} and R_2 subequal; m-cu from one-third to one-fourth its length beyond the fork of M; abdominal tergites weakly infuscated.

Sex?—Wing, 6 millimeters.

Head broken. Pronotum and mesonotum chiefly whitish gray, pruinose; præscutum with very faintly indicated intermediate stripes, scutal lobes weakly darkened; pleura whitish, the posterior parts vaguely more darkened. Mesonotum very high and gibbous. Halteres with stem whitened, knob broken. Legs with the coxæ and trochanters white; femora and tibiæ snowy white, the tips very narrowly blackened, on the femora including about

the outer twentieth, tibiæ with tips very narrowly to scarcely darkened; tarsi broken. Wings (Plate 3, fig. 22) whitish subhyaline, restrictedly patterned with narrow pale brown clouds, placed at Sc_2, origin of Rs, cord, outer end of cell 1st M_2 and R_2, best indicated by a darkening in color of the veins which otherwise are pale yellow. Venation: R_{1+2} and R_2 subequal; R_{2+3+4} distinct, subequal to the basal section of R_5; cell M_1 shorter than its petiole; m-cu about one-third to one-fourth its length beyond the fork of M; in one wing of the type basal section of M_3 slightly angulated, as figured.

Abdomen with the tergites weakly infuscated, sternites more yellowed: tip broken.

Habitat.—Nepal.

Holotype, Sex?, Simbhanjang Pass, altitude 8,190 feet, October 27, 1956 (*Coher*).

The most similar species is *Dicranota* (*Rhaphidolabina*) *spectralis* (Brunetti), of the eastern Himalayas, which differs in the coloration of the legs and in details of venation. Brunetti describes the tips of the femora and tibiæ of *spectralis* as being broadly black.

HEXATOMINI

TAIWANOMYIA PERPENDICULARIS (Alexander). **Plate 4, fig. 30.**

Troglophila perpendicularis ALEXANDER, Ann. Mag. Nat. Hist. XII 7 (1954) 602, 603.

The type male was from Doi Chom Cheng, Thailand, altitude 3,000 feet, February 17, 1953 (*Thurman*).

Male.—Length, about 4.5 millimeters; wing, 5; antenna, about 2.3.

General coloration of thoracic dorsum light brown, the pleura weakly infuscated above but not forming an evident stripe; wings (Plate 4, fig. 30) with a weak brownish tinge, unpatterned; vein R_{2+3} perpendicular or nearly so, subequal to R_2; cell 1st M_2 relatively small, shorter than M_4; male hypopygium with the apical point of the outer dististyle stout, the outer spine much more slender.

For a discussion of the synonymy of *Taiwanomyia* Alexander and *Troglophila* Brunetti, consult a paper by Alexander, Philip. Jour. Sci. 85 (1956) 360.

TAIWANOMYIA PERRETRACTA (Alexander). **Plate 4, fig. 31.**

Troglophila perretracta ALEXANDER, Ann. Mag. Nat. Hist. XII 7 (1954) 603.

The type female was from Dr. Buker's Cabin, Chiengmai, Thailand, February 4, 1953 (*Thurman*).

Female.—Length, about 5 millimeters; wing, 6.

General coloration of mesonotum light chestnut brown, pleura yellow, with a very conspicuous black longitudinal stripe; wings (Plate 4, fig. 31) with a strong brownish tinge, the stigma and a cloud over the anterior cord darker; cell M_1 present; m-cu lying far basad, about two-thirds its own length before the fork of M.

PARADELPHOMYIA (OXYRHIZA) DISSITA sp. nov.

General coloration of thoracic notum brown, the surface subnitidous; antennæ 16-segmented; thoracic pleura with a broad dark brown dorsal stripe; wings with a weak brownish tinge, stigma darker; abundant macrotrichia in cells of outer third of wing; veins R_3 and R_4 divergent, cell R_3 at margin approximately one and one-half to two times more extensive than cell R_2; cell M_1 present, m-cu beyond midlength of M_{3+4}; male hypopygium with the outer dististyle slender, with two apical blackened teeth and a remote spine on inner margin; gonapophysis and ædeagus elongate.

Male.—Length, about 4.5 to 5 millimeters; wing, 5 to 5.5; antenna, about 1.2.

Female.—Length, about 6 millimeters; wing, 5.5.

Rostrum dark brown; palpi black. Antennæ 16-segmented, brownish black; basal flagellar segments long-oval, the outer ones passing into elongate, a little exceeding their verticils. Head dark brown.

Pronotum brown. Mesonotum brown, the surface subnitidous, the humeral region restrictedly more yellowed; posterior sclerites of notum a trifle darker brown; pleurotergite and sides of the mediotergite more reddened. Pleura with a broad dark brown dorsal stripe, the ventral sclerites more reddish brown. Halteres with stem dirty white, knob infuscated. Legs with all coxæ reddish brown; trochanters yellow; remainder of legs brownish yellow, conspicuously hairy. Wings with a weak brownish tinge, stigma still darker; veins brown. Abundant macrotrichia in the cells of outer third of wing, along the posterior margin extending as far basad as the end of cell 1st A. Venation: Sc_1 ending shortly before fork of Rs, Sc_2 far from its tip. Sc_1 subequal to R_{2+3+4}; veins R_3 and R_4 divergent, cell

R_3 at margin approximately one and one-half to two times as extensive as cell R_2; cell M_1 present, about one-third to one-fourth its petiole; m-cu beyond midlength of M_{3+4}.

Abdominal tergites brown, subterminal segments dark brown to form a ring; sternites and hypopygium more reddish brown. Male hypopygium with the dististyles terminal; outer style unusually slender, terminating in two blackened teeth, the innermost stouter and slightly curved; at near two-thirds the length of the style on inner margin with an isolated more slender spine; inner style broad basally, narrowed to the obtuse tip, in the axil at its base with a very low setiferous lobule. Gonapophyses and ædeagus elongate, conspicuous, the latter sinuous, curved at apex.

Habitat.—Pakistan (Northwest Frontier Province).

Holotype, male, Kaghan, altitude 6,688 feet, June 27, 1953 (*Schmid*). Allotopotype, female, pinned with the type. Paratypes, 5 males and females, Murree Hills, altitude 7,242 feet, June 10, 1953 (*Schmid*).

Paradelphomyia (*Oxyrhiza*) *dissita* is quite distinct from *P.*(*O.*) *flavescens* (Brunetti) from the eastern Himalayas, differing in the coloration of the body, coloration and venation of the wings and, especially, in the structure of the male hypopygium.

PARADELPHOMYIA (OXYRHIZA) NEWAR Alexander. **Plate 4, figs. 32, 40.**

Paradelphomyia (*Oxyrhiza*) *newar* ALEXANDER, Journ. N.Y. Ent. Soc. 71 (1958). In press.

The numerous types were from Simbhanjang Pass, Nepal, altitude 8,190 feet, October 1 to 27, 1956 (*Coher*).

Male.—Length, about 5.5 to 6 millimeters; wing, 6 to 7.

Female.—Length, about 6 to 6.5 millimeters; wing, 6.5 to 7.

Size large (wing, 6 millimeters or more); mesonotal præscutum light brown, posterior sclerites of notum and the pleura yellow; wings (Plate 4, fig. 32) pale yellowish gray, unpatterned except for the pale brown stigma; outer cells of wing with numerous macrotrichia; cell M_1 present; abdominal tergites light brown, eight segment darker brown to form a narrow subterminal ring; male hypopygium (Plate 4, fig. 40) with the basistyle, *b*, produced at apex into a small spine, the dististyles, *d*, thus slightly subterminal in position; outer style terminating in two acute spines separated by a narrow notch, axial spine

longer; inner style stout, its tip obtuse; spines of the ventral fork very slender, almost setaceous.

PARADELPHOMYIA (OXYRHIZA) NUBIFERA Alexander. **Plate 4, fig. 33.**

Paradelphomyia (Oxyrhiza) nubifera ALEXANDER, Ann. Mag. Nat. Hist. XII 7 (1954) 600, 601.

The types, females, were from Doi Chom Cheng, Thailand, altitude 3,000 feet, January 1 to 2, 1953 (*Prayoon*).

Female.—Length, about 5 to 5.5 millimeters; wing, 4.5 to 5.

General coloration of thoracic dorsum brownish yellow, the postnotum and pleura blackened; basal segments of antennæ pale, the flagellar segments of antennæ beyond the first black; head silvery gray; legs yellow, the outer tarsal segments darkened; wings (Plate 4, fig. 33) whitish subhyaline, spotted and clouded with brown, including a larger almost continuous area over the cord; vein R_2 at or close to the fork of R_{2+3+4}.

PARADELPHOMYIA (OXYRHIZA) PRAYOONI Alexander. **Plate 4, figs. 34, 41.**

Paradelphomyia (Oxyrhiza) prayooni ALEXANDER, Ann. Mag. Nat. Hist. XII 7 (1954) 598–600.

The types, of both sexes, were from Doi Chom Cheng, Thailand, altitude 3,000 feet, January 2 to 3, 1953 (*Prayoon*).

Male.—Length, about 4.5 millimeters; wing, 5.

Female.—Length, about 5.5 millimeters; wing, 6.

General coloration of thorax obscure brownish yellow, the præscutum with three more or less distinct darker stripes, dorsal thoracic pleura blackened; rostrum yellow; legs yellow, the tips of the femora conspicuously black, of the tibiæ less distinctly so; wings (Plate 4, fig. 34) whitish, restrictedly patterned with brown; macrotrichia in outer cells of wing; vein R_2 some distance before the fork, leaving a distinct element R_{3+4}; cell M_1 present; abdominal tergites more or less bicolored; male hypopygium (Plate 4, fig. 41) with the tergite produced medially into an oval lobe; basistyle, *b*, slightly produced at apex, dististyles, *d*, virtually terminal, outer style with the two outer spines slightly dissimilar in shape; ventral fork of ædeagus appearing as two long separated spines.

PSEUDOLIMNOPHILA ERNESTINA Alexander. **Plate 4, fig. 35.**

Pseudolimnophila ernestina ALEXANDER, Ann. Mag. Nat. Hist. XII 6 (1953) 754, 755.

The type, a female, was from Chiengmai, Thailand, altitude 1,000 feet, taken by Mrs. Ernestine B. Thurman, to whom the species was dedicated.

Female.—Length, about 5.5 millimeters; wing, 5.5.

General coloration brownish yellow, the præscutum with four brown stripes; antennal scape and pedicel brownish black, first flagellar segment yellow, the others brown; thoracic pleura pale brown, conspicuously patterned with darker brown; legs brownish yellow; wings (Plate 4, fig. 35) with a weak brown tinge; vein Sc relatively short, Sc_1 ending a short distance before the fork of Rs; vein R_2 far before the fork, R_{3+4} being nearly one-half of vein R_3 alone; cell M_1 present but small; m-cu at near one-third the length of M_{3+4}.

LIMNOPHILA (ELÆOPHILA) BICOLORATA Alexander. **Plate 4, fig. 36.**

Limnophila (*Elæophila*) *bicolorata* ALEXANDER, Journ. N. Y. Ent. Soc. 71 (1958). In press.

The types, females, are from Amlekhgang, Nepal, altitude, 1,690 feet, December 2, 1956, and from Bhainse, December 8, 1956 (*Coher*).

Female.—Length, about 8 to 9 millimeters; wing, 6.5 to 7.

Size medium (wing of female about 7 millimeters); mesonotum gray, the præscutum lined with darker; a central darkened vitta on posterior sclerites; antennal flagellum bicolored; femora yellow, with a narrow brown subterminal ring, the actual tip paler; wings (Plate 4, fig. 36) whitened, with a heavy spotted and dotted dark brown pattern; abdomen brownish black.

ERIOPTERINI

TRENTEPOHLIA (MONGOMA) ALBOPOSTICATA sp. nov. **Plate 4, fig. 37.**

General coloration of mesonotum light brown, the præscutum with a central dark brown stripe, each scutal lobe with a brown spot; pleura chiefly yellow, dorsal sclerites weakly darkened; legs black, the fore and middle tarsi brownish white, posterior legs with the outer end of tibia and proximal three-fourths of basitarsus snowy white, the outer tarsal segments brownish black; wings subhyaline, stigma darker.

Male.—Length, about 7 millimeters; wing, 7.3.

Rostrum yellow; maxillary palpi black. Antennæ with scape obscure yellow, remainder of organ black; flagellar segments elongate, subequal to the longest verticils; terminal segment a

little longer than the penultimate. Head blackish gray; anterior vertex narrow, carinate, as common in the genus.

Cervical sclerites obscure yellow. Pronotal scutum brown, with a few conspicuous erect black setæ, scutellum obscure yellow. Mesonotal præscutum light brown, with a conspicuous dark brown central stripe, wider and more intense in front, the posterior end narrowly divided; scutum brownish yellow, midregion yellow, each lobe with a conspicuous brown area on mesal part, lateral margin of scutal lobe with a few strong black setæ, scutellum brownish testaceous, parascutella clearer yellow; mediotergite chiefly dark brown, paling to obscure yellow on sides, pleurotergite yellow. Pleura chiefly yellow, the dorsal part, including the dorsopleural membrane, weakly darkened. Halteres brownish black, base of stem restrictedly yellow. Legs with the fore coxæ infuscated, remaining coxæ and all trochanters yellow; femora and tibiæ brownish black to black, fore and middle tarsi brownish white; posterior tibia black with about the outer eighth snowy white; basitarsus snowy white for most of its extent, with about the outer fourth and remaining tarsal segments brownish black; fore and middle femora at base with a row of seven or more black setæ, posterior femora with two or three slightly longer bristles. Wings (Plate 4, fig. 37) subhyaline, the narrow and inconspicuous stigma and the vague apex slightly darker; veins brown. Venation: R_{3+4} more than one-third R_2; cell R_3 broad at margin, about two and one-half times R_2; R_{2+3+4} longer than Rs; m-cu close to fork of M; apical fusion of veins Cu_1 and 1st A moderate, subequal to m.

Abdominal tergites brownish black, the fifth and outer tergites paler brown; sternites light yellow; hypopygium obscure yellow, styli black.

Habitat.—South India.

Holotype, male, Mattupalayam, Coimbatore District, October 1956 (*Susai Nathan*).

The most similar regional species include *Trentepohlia* (*Mongoma*) *pallidiventris* (Brunetti) and *T.* (*M.*) *bombayensis* Edwards, which have the leg coloration quite distinct, with the pattern generally similar on all legs. The present fly has only the posterior legs whitened and differs further in the black coloration of all outer tarsal segments.

TEUCHOLABIS (TEUCHOLABIS) PARAPLECIOIDES sp. nov. **Plate 4, fig. 38.**

Generally similar to *plecioides;* head black; prothorax broadly orange behind; thoracic notum and pleura orange; antennæ,

halteres and legs black; wings tinged with brown, the costal and outer radial fields darker; Sc long, Sc_1 ending opposite R_2; R_{1+2} about three times R_2; m-cu its own length beyond the fork of M; abdomen black.

Female.—Length, about 7.5 millimeters; wing, 6.8.

Rostrum, palpi and antennæ black. Head black.

Pronotum black on anterior half, orange behind. Mesothorax, including pleura, entirely dull orange. Halteres black. Legs with coxæ orange; remainder of legs uniformly black. Wings (Plate 4, fig. 38) tinged with brown, the prearcular, costal and outer radial fields much darker, the stigmal area scarsely differentiated from the coloration in cell R_2; vague pale longitudinal streaks in cell R adjoining vein M, along central part of cell Cu, and in the base of cell 1st A, adjoining the vein; veins brown. Venation; Sc long, Sc_1 ending opposite R_2; R_{1+2} long, about three times R_2; m-cu about its own length beyond the fork of M; vein 2nd A longer than in *plecioides*.

Abdomen black, only the cerci paler, horn-yellow.

Habitat.—Nepal.

Holotype, female, Amlekhgang, altitude 1,690 feet, March 17, 1956 (*Coher*).

The most similar species is *Teucholabis* (*Teucholabis*) *plecioides* de Meijere, of Java and Sumatra, which differs in the details of body coloration and venation, as indicated in the diagnosis. The male specimen recorded from Pahang, Malay Peninsula, by Edwards [Journ. Fed. Malay St. Mus. 14 (1928) 95] may possibly pertain to the present species or may represent a still further member of this particular group.

TEUCHOLABIS (TEUCHOLABIS) PROGNE Alexander. **Plate 4, fig. 39.**

Teucholabis (*Teucholabis*) *progne* ALEXANDER, Ann. Mag. Nat. Hist. XII 3 (1950) 687, 688.

The type male was from Cameron Highlands, Pahang, Malaya, altitude 4,800 feet, July 1948 (*Noël L. H. Krauss*).

Male.—Length, about 5.5 to 6 millimeters; wing, 5.5 to 6.

Mesonotum chiefly polished black, the humeral region of the præscutum extensively yellow; vertex polished brown; knob of halteres light yellow; femora yellow; wings (Plate 4, fig. 39) broad, pale yellow, virtually unpatterned, stigma oval, brown; abdominal segments bicolored, yellow and dark brown; male hypopygium with the outer dististyle an elongate flattened blade, the inner style much larger.

TEUCHOLABIS (TEUCHOLABIS) THURMANI Alexander. **Plate 4, fig. 42.**

Teucholabis (*Teucholabis*) *thurmani* ALEXANDER, Ann. Mag. Nat. Hist. XII 7 (1954) 603, 604.

The types, all males, were from Doi Chom Cheng, Thailand, altitude 3,000 feet, May 4 to 10, 1952 (*Thurman*).

Male.—Length, about 8 millimeters; wing, 7.5.

Head, abdomen, antennæ, halteres and legs black, thorax orange; wings whitish subhyaline, patterned with brown, including cells C and Sc, broad band at cord, and the darkened apex, the latter two areas interconnected posteriorly; male hypopygium (Plate 4, fig. 42) with the dististyles, *d*, terminal in position; outer style simple, gently curved, the concave face at near midlength produced into a broad tooth; inner style tripartite, the largest or inner arm extended into a slender terminal spine, intermediate arm a shorter cylinder with four very long apical setæ, the outermost arm a slender simple spine.

GNOPHOMYIA (GNOPHOMYIA) ANAPHORA Alexander. **Plate 5, figs. 43, 50.**

Gnophomyia (*Gnophomyia*) *anaphora* ALEXANDER, Ann. Mag. Nat. Hist. XII 7 (1954) 604, 605.

The types were from Doi Chom Cheng, Thailand, altitude 3,000 feet, January 1 to 3, 1953, and the Wat, Doi Sutep, Thailand, altitude 2,000 feet, January 18, 1953 (*Prayoon & Thurman*).

Male.—Length, about 5 to 5.2 millimeters; wing, 5.5 to 5.8; antenna, about 2.5 to 2.6.

Female.—Length, about 5.2 millimeters; wing, 5.8.

General coloration of mesonotum reddish brown, darker behind; pleura yellow ventrally, the dorsal part with a broad black longitudinal stripe that is almost continuous; wings (Plate 5, fig. 43) subhyaline, the oval stigma medium brown, Sc long; male hypopygium (Plate 5, fig. 50) with the outer dististyle, *d*, simple, gently curved, narrowed to the subacute tip; phallosome, *p*, a central asymmetrical plate that narrows at apex into a blackened knob.

GNOPHOMYIA (GNOPHOMYIA) NEBULICINCTA Alexander. **Plate 5, fig. 44.**

Gnophomyia (*Gnophomyia*) *nebulicincta* ALEXANDER, Ann. Mag. Nat. Hist. XII 7 (1954) 605, 606.

The types were from the Wat, Doi Sutep, Thailand, altitude 2,000 feet, January 18, 1953 (*Prayoon*).

Male.—Length, about 4.2 to 4.5 millimeters; wing, 4.7 to 5; antenna, about 1.8 to 2.0

Size relatively small (wing of male 5 millimeters or less); general coloration black, restrictedly patterned with yellow; antennæ relatively long, exceeding one-third the length of wing; legs brown; wings (Plate 5, fig. 44) subhyaline, extensively clouded with pale brown before and just beyond the cord; male hypopygium with the outer dististyle slender, glabrous, narrowed to a subacute point, inner style shorter, enlarged at base; two sets of gonapophyses, the lateral pair large and powerful, very strongly bent, the inner pair subtending the somewhat shorter ædeagus.

GONOMYIA (PROTOGONOMYIA) NAMTOKENSIS Alexander. **Plate 5, figs. 45, 51.**

Gonomyia (*Protogonomyia*) *namtokensis* ALEXANDER, Ann. Mag. Nat. Hist. XII 6 (1953) 911.

The types, males, were from Nam Tok (water falls), præ, Thailand, altitude 2,000 feet, February 14, 1952 (*Thurman*).

Male.—Length, about 5 to 5.2 millimeters; wing, 6 to 6.2.

Female.—Length, about 4.5 to 5 millimeters; wing, 5 to 5.5.

General coloration brownish gray, variegated with paler; thoracic pleura striped longitudinally with dark brown; femora yellowish brown; wings (Plate 5, fig. 45) with a weak brownish tinge, the stigma darker; male hypopygium (Plate 5, fig. 51) with three dististyles, *d*, the outermost a sinuous glabrous blade, its apex expanded, obtuse; intermediate style unequally forked; inner style a clavate blade that is provided with retrorse setæ.

GONOMYIA (IDIOCERA) THAIICOLA Alexander. **Plate 5, figs. 46, 52.**

Gonomyia (*Idiocera*) *thaiicola* ALEXANDER, Ann. Mag. Nat. Hist. XII 6 (1953) 912.

The types, representing both sexes, were from Chiengmai, Thailand, May 19, 1952 (*Thurman*).

Male.—Length, about 4 millimeters; wing, 4.

Female.—Length, about 4.5 to 5 millimeters; wing, 5 to 5.5.

General coloration brown, the ventral half of the thoracic pleura more yellowed; head dark gray; rostrum, palpi and antennæ black; wings (Plate 5, fig. 46) weakly infuscated, the stigma not or scarsely darker; Sc short, cell R_3 relatively small; male hypopygium (Plate 5, fig. 52) with the outer dististyle, *d*, a long needlelike spine; intermediate style bifid, its outer arm a long flattened blade that bears a blackened recurved point on inner margin at near one-third the length, the inner arm again forking into two parts; inner style a simple rod, pointed at apex.

CRYPTOLABIS (BÆOURA) SUBNEBULA sp. nov. **Plate 5, fig. 47.**

Head and mesonotum light gray, without clearly defined pattern; antennæ dark brown, flagellar verticils very long; legs brown; wings subhyaline, vaguely clouded with darker; Sc_1 ending about opposite one-third the length of R_{2+3+4}, Sc_2 before the fork of Rs.

Female.—Length, about 4 millimeters; wing, 4.5.

Rostrum dark brown, palpi somewhat paler brown. Antennæ dark brown, the basal segments even more darkened; flagellar segments oval, the outer ones more elongate but still shorter than the long conspicuous verticils. Head light gray; anterior vertex broad.

Pronotum brownish gray, sides of scutellum yellowish brown. Mesonotal præscutum and scutum gray, the former virtually unicolorous above, with three rows of setæ to indicate the usual interspaces. Posterior sclerites of notum and the pleura damaged but presumably gray. Halteres broken. Legs with the fore coxæ dark brown, remaining coxæ and all trochanters obscure yellow; femora obscure brownish yellow, darker outwardly, tips narrowly still darker; remainder of legs light brown, the outer tarsal segments more blackened; femora and succeeding segments with very long and conspicuous setæ. Wings (Plate 5, fig. 47) subhyaline, vaguely clouded with still darker, especially at stigma and over the cord; less evident cloudings along vein R_5 and in cells M, Cu, 1st A and 2nd A; veins brown, more yellowed at base. Costal fringe long and conspicuous. Venation: Sc_1 ending about opposite one-third the length of R_{2+3+4}, Sc_2 before the fork of Rs; cell 2nd A relatively broad.

Abdomen brown, the terminal segments still darker. Ovipositor with the cerci oval, fleshy, with numerous setæ.

Habitat.—Nepal.

Holotype, female, Baridamar, altitude 1,690 feet, August 7, 1956 (*Coher*).

The most similar regional species is *Cryptolabis* (*Bæoura*) *distans* (Brunetti) which is described as having the wings pale gray and with the mesonotum wholly blackish, with a slight pruinosity.

ERIOPTERA (ERIOPTERA) SUBHALTERATA sp. nov. **Plate 5, figs. 48, 53.**

General coloration of mesonotal præscutum light grayish brown, the lateral borders broadly yellow; dorsal thoracic pleurites with a brown longitudinal stripe; halteres with blackened knobs; legs yellow; wings yellowed, with a vague

darkened seam over the anterior cord; male hypopygium with the outer dististyle a simple blade that narrows to an acute point, inner style with its outer half produced into an unarmed club; gonapophysis a simple blackened rod, the tip acute.

Male.—Length, about 5 to 6 millimeters; wing, 6 to 7.

Female.—Length, about 5.5 millimeters; wing, 6.

Rostrum and palpi brownish black. Antennæ with scape dark brown to brownish black, pedicel yellow to light brown, basal flagellar segments yellowed, outer ones somewhat darker; flagellar segments long-oval, exceeding the verticils. Head brownish gray on central part, the sides of vertex more buffy to yellow.

Pronotum brown medially, yellow on sides, including the pretergites. Mesonotal præscutum with four light grayish brown stripes, the interspaces slightly darker brown, including the median vitta which is broader and somewhat darker in front; humeral and lateral borders broadly light yellow; scutal lobes light brown, more or less pruinose, central area more yellowed; scutellum pale, weakly darkened on disk; postnotum brownish gray, the suture more yellowed. Pleura brownish yellow or light brown on ventral portion, with a broad darker brown longitudinal stripe, from and including the fore coxæ, widened behind, reaching the abdomen at the halteres; dorsopleural region light yellow. Halteres with stem light yellow, knob abruptly black. Legs with fore coxæ darkened, as described, remaining coxæ and trochanters yellow, femora yellow, tips not or but weakly darkened; tibiæ and tarsi yellow, the two outer tarsal segments darker. Wings (Plate 5, fig. 48) yellowed, the prearcular and costal regions clearer yellow; a darkened cloud over the anterior cord, best-indicated by a deepening in color of the veins, remaining veins yellow. Venation: m-cu at fork of M; vein 2nd A very strongly sinuous.

Abdomen chiefly dark brown, the extreme posterior borders of the segments pale, hypopygium dark brown; in female the sternites paler. Male hypopygium (Plate 5, fig. 53) with the inner apical lobe of basistyle, *b*, produced. Outer dististyle, *d*, a simple blade, narrowed to an acute point, the inner margin of the outer two-thirds slightly produced into a flange; inner style shorter, the basal half stout, the remainder prolonged into an obtuse club, outer margin at midlength with a tiny pale tubercle that bears a single microscopic seta. Phallosome, *p*, including a pair of simple gonapophyses, blackened and outcurved on outer half, tips acute.

Habitat.—Nepal.

Holotype, male, Simbhanjang Pass, altitude 8,190 feet, October 1, 1956 (*Coher*). Allotopotype, female pinned with the type. Paratopotypes, several of both sexes, mostly damaged, October 1 to 27, 1956.

Most similar to *Erioptera* (*Erioptera*) *halterata* Brunetti, differing in the coloration of the thoracic dorsum and pleura, weakly patterned wings, and structure of the male hypopygium. Brunetti's very brief description of the dististyles of the hypopygium of *halterata* cannot refer to the present fly.

ERIOPTERA TIRO Alexander. **Plate 5, fig. 49.**

Erioptera (*Erioptera*) *tiro* ALEXANDER, Ann. Mag. Nat. Hist. XII 7 (1954) 607, 608.

The type female was from the Wat, Doi Sutep, Thailand, altitude 2,000 feet, January 18, 1953 (*Prayoon*).

Female.—Length, about 4.5 millimeters; wing, 5.2.

General coloration of mesonotum brownish gray, the posterior pleurites yellowed; halteres darkened; wings (Plate 5, fig. 49) with a brownish tinge, more saturated in the cells beyond the cord, restrictedly patterned with still darker brown; R_{2+3+4} short and subperpendicular, about one-third longer than R_{2+3}; vein 2nd A long and strongly sinuous; ovipositor very long and slender, the valves nearly straight.

MOLOPHILUS (MOLOPHILUS) DIVERSILOBUS sp. nov.

Belongs to the *gracilis* group and subgroup; general coloration of the notum dark brown, pleura darkened dorsally; halteres yellow; male hypopygium fulvous; ventral lobe of basistyle bilobed, both dististyles slender, pointed at tips.

Male.—Length, about 4 to 4.3 millimeters; wing, 4.5 to 5.

Female.—Length, about 4.2 millimeters; wing, 4.5.

Rostrum brownish yellow; palpi dark brown. Antennæ short; basal segments brownish yellow, outer ones more infuscated, oval, with long verticils. Head dark gray.

Pronotum and pretergities obscure yellow. Mesonotal præscutum and scutum dark brown, sparsely pruinose; humeral region of præscutum yellow, pseudosutural foveæ brown; scutellum a trifle paler, in cases definitely yellowed; postnotum brown. Pleura dark brown dorsally, the ventral half paler. Halteres pale yellow. Legs with coxæ and trochanters yellow; femora

and tibiæ yellow, tips infuscated; tarsi brown. Wings grayish yellow, prearcular and costal fields clearer yellow; veins obscure yellow, trichia brown. Venation; R_2 lying shortly beyond the level of r-m; petiole of cell M_3 nearly three times m-cu; vein 2nd A sinuous, ending shortly beyond the level of m-cu.

Abdomen dark brown, hypopygium conspicuously light fulvous. Male hypopygium with the dorsal lobe of the basistyle relatively slender, with long setæ; ventral lobe moderately produced, bearing an obtusely rounded knob or lobule at its base. Dististyles slender, subequal in length and thickness, both pointed at tips, one more abruptly so.

Habitat.—Pakistan (Northwest Frontier Province).

Holotype, male, Valleé de Barthé, July 28, 1953 (*Schmid*). Allotopotype, female. Paratopotypes, several males.

Readily distinguished from other generally similar regional members of the *gracilis* group by the structure of the male hypopygium. It is closest to the species next described as *Molophilus* (*Molophilous*) *extensilobus* sp. nov.

MOLOPHILUS (MOLOPHILUS) EXTENSILOBUS sp. nov.

Belongs to the *gracilis* group and subgroup, allied to *diversilobus;* general coloration of mesonotum dark brownish gray or plumbeous, scutellum yellowed; antennæ brownish black; male hypopygium with the ventral lobe of the basistyle greatly extended, longer than the dististyles, the latter unequal in diameter.

Male.—Length, about 3.3 to 3.5 millimeters; wing, 3.8 to 4.

Female.—Length, about 4 millimeters; wing, 4.

Rostrum and palpi brownish black. Antennæ brownish black throughout; flagellar segments oval, with long verticils. Head gray.

Pronotum chiefly infuscated, the scutellum and pretergites narrowly pale. Mesonotum chiefly dark brownish gray, the humeral region of the præscutum only vaguely more brightened; pseudosutural foveæ brownish black; scutellum obscure yellow. Pleura uniformly dark gray or plumbeous. Halteres pale yellow. Legs with coxæ yellow, the fore pair darker; trochanters yellow; remainder of legs brown to dark brown, femoral bases paler. Wings grayish yellow, the prearcular and costal regions brightened; viens and trichia darker brown. Venation: R_2 in virtual transverse alignment with r-m; petiole of cell M_3 about three times m-cu; vein 2nd A sinuous, ending nearly opposite m-cu.

Abdomen dark brown, genitalia brightened. Male hypopygium generally as in *diversilobus;* ventral lobe of basistyle greatly extended, longer than the dististyles, narrowed to a subacute point, the basal lobule large and conspicous. Dististyles unequal in diameter, the basal half of one expanded, approximately twice as thick as the second style.

Habitat.—Kashmir and Pakistan.

Holotype, male, Surgun sur, Pakistan, altitude 6,875 feet, July 29, 1953 (*Schmid*). Allotopotype, female, pinned with type. Paratopotype, 1 female; paratypes, males and females, Kel, Kashmir, altitude 6,544 feet, May 19, 1954 (*Schmid*).

Molophilus (*Molophilus*) *extensilobus* is separated from *M.* (*M.*) *diversilobus* sp. nov., by the smaller size, darker color of the body and antennæ and, especially, by the structure of the male hypopygium, particularly the basistyle and dististyles.

STYRINGOMYIA CAUDIFERA Alexander. **Plate 5, fig. 54.**

Styringomyia caudifera ALEXANDER, Ann. Mag. Nat. Hist. XII 6 (1953) 913, 914.

The type male was from Chiengmai, Thailand, August 17, 1952 (*Thurman*).

Male.—Length, about 7 millimeters; wing, 4.8.

Mesonotal præscutum with more than the anterior half brownish black, the posterior half, with the centers of the scutal lobes and a central line on the scutellum yellow; wings with four larger brown spots and small marginal darkenings at ends of the veins; male hypopygium (Plate 5, fig. 54) with the sternite, *s,* relatively broad, the two setæ separated; intermediate arm of dististyle, *d,* produced into an acute beak with a smaller subtending spine; phallosome, *p,* including a long curved posterior spine and a pair of small blackened beaks.

ILLUSTRATIONS

[Legend: *a*, ædeagus; *b*, basistyle; *d*, dististyle; *g*, gonapophysis; *p*, phallosome; *s*, sternite; *t*, *tergite*.]

Plate 1

Fig. 1. *Dolichopeza* (*Nesopeza*) *angustissima* sp. nov.; venation.
2. *Tipula* (*Schummelia*) *lama* Alexander; venation.
3. *Tipula* (*Schummelia*) *notomelania* Alexander; venation.
4. *Tipula* (*Tipulodina*) *subscimitar* Alexander; venation.
5. *Dolichopeza* (*Nesopeza*) *angustissima* sp. nov.; male hypopygium.
6. *Tipula* (*Schummelia*) *notomelania* Alexander; male hypopygium.
7. *Tipula* (*Tipulodina*) *forficuloides* Alexander; male hypopygium.
8. *Tipula* (*Tipulodina*) *malabarensis* sp. nov.; male hypopygium.
9. *Tipula* (*Tipulodina*) *subscimitar* Alexander; male hypopyguim.

Plate 2

Fig. 10. *Tipula* (*Vestiplex*) *gurkha* Alexander; male hypopygium.
11. *Tipula* (*Vestiplex*) *lepcha* Alexander; male hypopygium.
12. *Tipula* (*Indotipula*) *blandita* Alexander; male hypopygium.
13. *Tipula shawiana* Alexander; male hypopygium.
14. *Limonia* (*Limonia*) *micropyga* Alexander; venation.
15. *Limonia* (*Limonia*) *perdocta* Alexander; venation.
16. *Limonia* (*Limonia*) *sielediva* sp. nov.; venation.
17. *Limonia* (*Limonia*) *tagax* Alexander; venation.
18. *Limonia* (*Limonia*) *vajra* Alexander; venation.

Plate 3

Fig. 19. *Limonia* (*Geranomyia*) *ganesa* sp. nov.; venation.
20. *Orimarga* (*Orimarga*) *sherpa* Alexander; venation.
21. *Antocha* (*Antocha*) *perstudiosa* Alexander; venation.
22. *Dicranota* (*Rhaphidolabina*) *subspectralis* sp. nov.; venation.
23. *Dicranota* (*Rhaphidolabis*) *furcistyla* Alexander; venation.
24. *Limonia* (*Limonia*) *sielediva* sp. nov.; male hypopygium.
25. *Limonia* (*Limonia*) *micropyga* Alexander; male hypopygium.
26. *Limonia* (*Limonia*) *vajra* Alexander; male hypopygium.
27. *Limonia* (*Geranomyia*) *ganesa* sp. nov.; male hypopygium.
28. *Antocha* (*Antocha*) *perstudiosa* Alexander; male hypopygium.
29. *Dicranota* (*Rhaphidolabis*) *furcistyla* Alexander; male hypopygium.

Illustrations

Plate 4

Fig. 30. *Taiwanomyia perpendicularis* (Alexander); venation.
31. *Taiwanomyia perretracta* (Alexander); venation.
32. *Paradelphomyia* (*Oxyrhiza*) *newar* Alexander; venation.
33. *Paradelphomyia* (*Oxyrhiza*) *nubifera* Alexander; venation.
34. *Paradelphomyia* (*Oxyrhiza*) *prayooni* Alexander; venation.
35. *Pseudolimnophila ernestina* Alexander; venation.
36. *Limnophila* (*Elæophila*) *bicolorata* Alexander; venation.
37. *Trentepohlia* (*Mongoma*) *albopostícata* sp. nov.; venation.
38. *Teucholabis* (*Teucholabis*) *paraplecioides* sp. nov.; venation.
39. *Teucholabis* (*Teucholabis*) *progne* Alexander; venation.
40. *Paradelphomyia* (*Oxyrhiza*) *newar* Alexander; male hypopygium.
41. *Paradelphomyia* (*Oxyrhiza*) *prayooni* Alexander; male hypopygium.
42. *Teucholabis* (*Teucholabis*) *thurmani* Alexander; male hypopygium.

Plate 5

Fig. 43. *Gnophomyia* (*Gnophomyia*) *anaphora* Alexander; venation.
44. *Gnophomyia* (*Gnophomyia*) *nebulicincta* Alexander; venation.
45. *Gonomyia* (*Protogonomyia*) *namtokensis* Alexander; venation.
46. *Gonomyia* (*Idiocera*) *thaiicola* Alexander; venation.
47. *Cryptolabis* (*Bæoura*) *subnebula* sp. nov.; venation.
48. *Erioptera* (*Erioptera*) *subhalterata* sp. nov.; venation.
49. *Erioptera tiro* Alexander; venation.
50. *Gnophomyia* (*Gnophomyia*) *anaphora* Alexander; male hypopygium.
51. *Gonomyia* (*Protogonomyia*) *namtokensis* Alexander; male hypopygium.
52. *Gonomyia* (*Idiocera*) *thaiicola* Alexander; male hypopygium.
53. *Erioptera* (*Erioptera*) *subhalterata* sp. nov.; male hypopygium.
54. *Styringomyia caudifera* Alexander; male hypopygium.

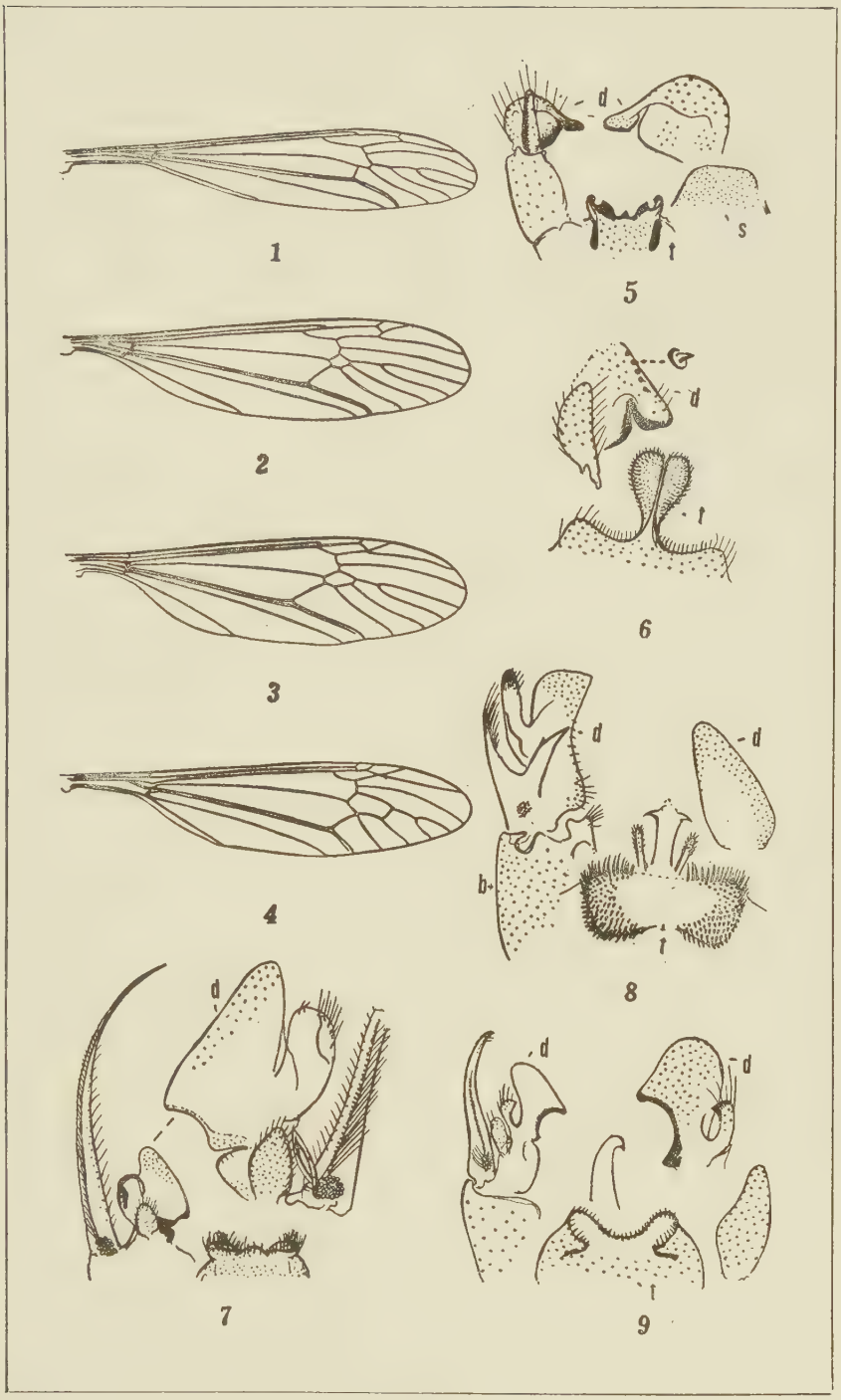
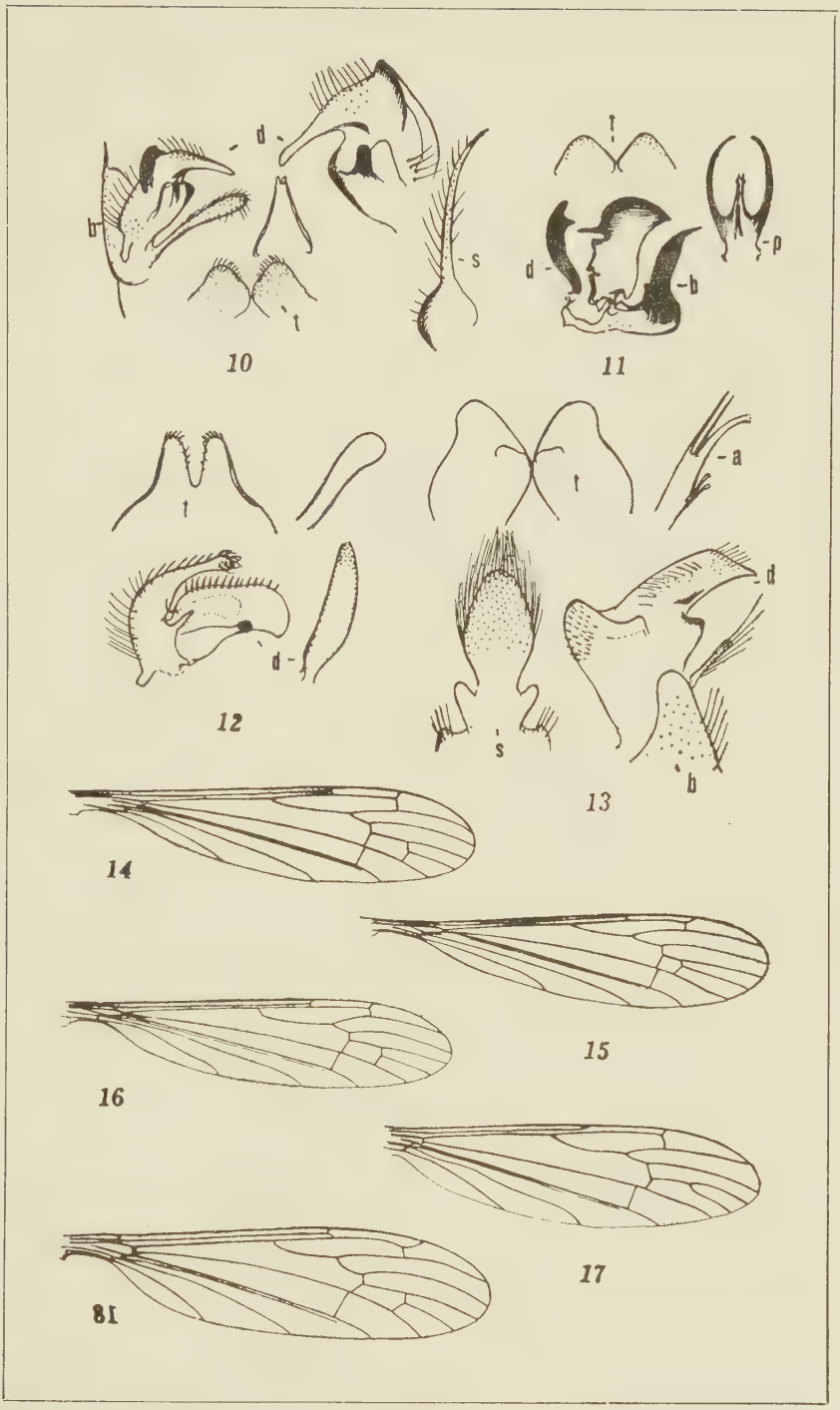


PLATE 1.



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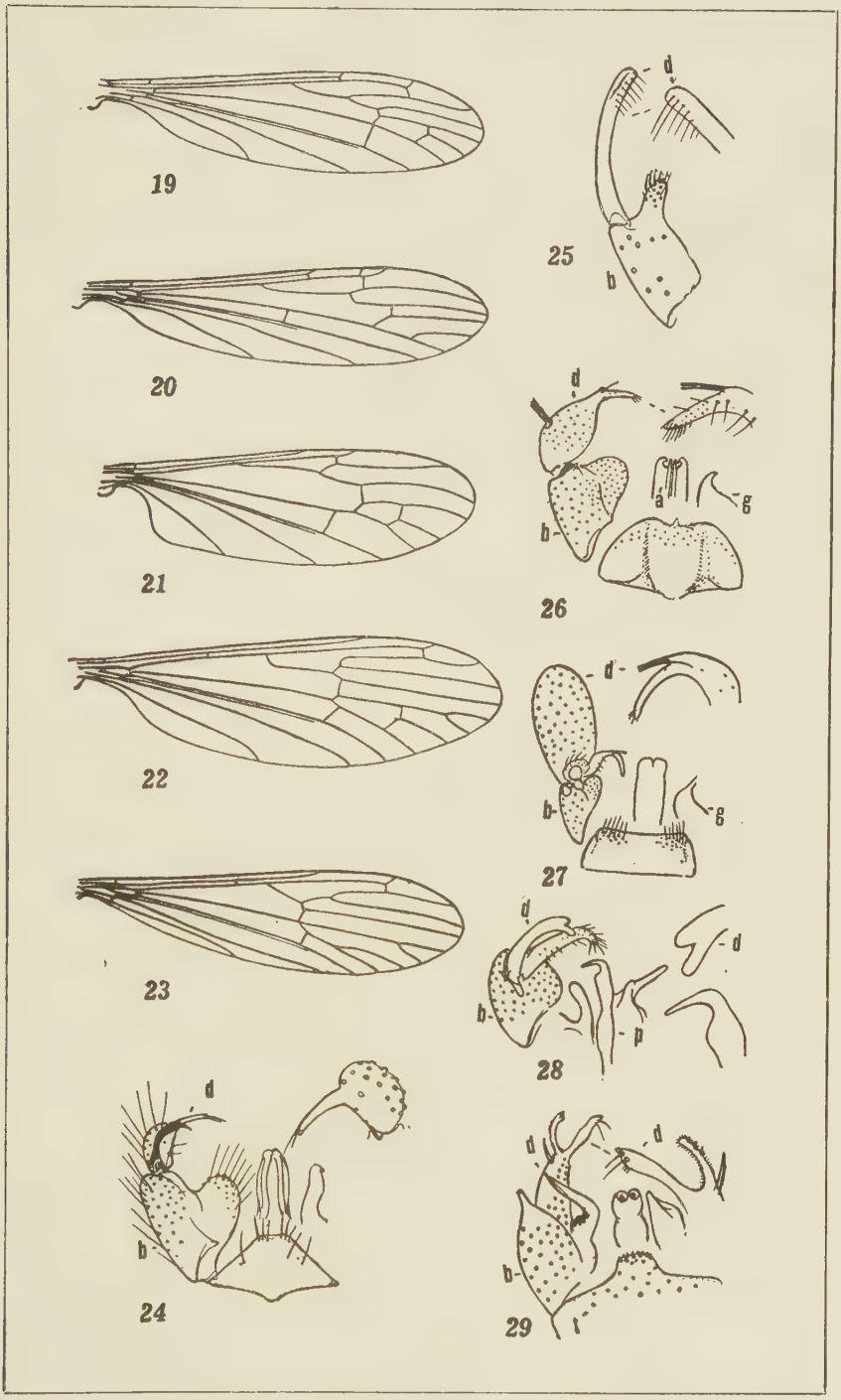

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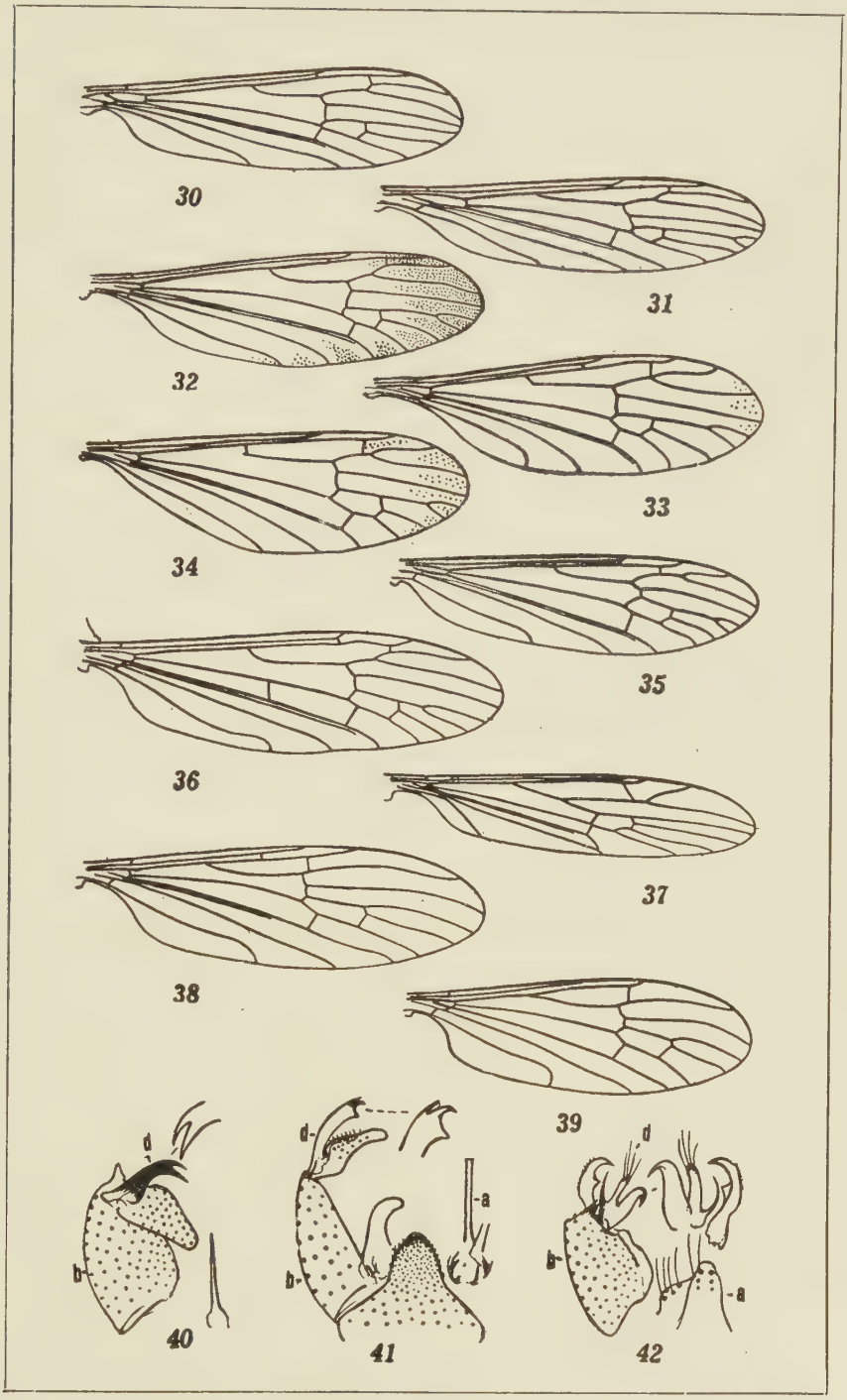


PLATE 4.

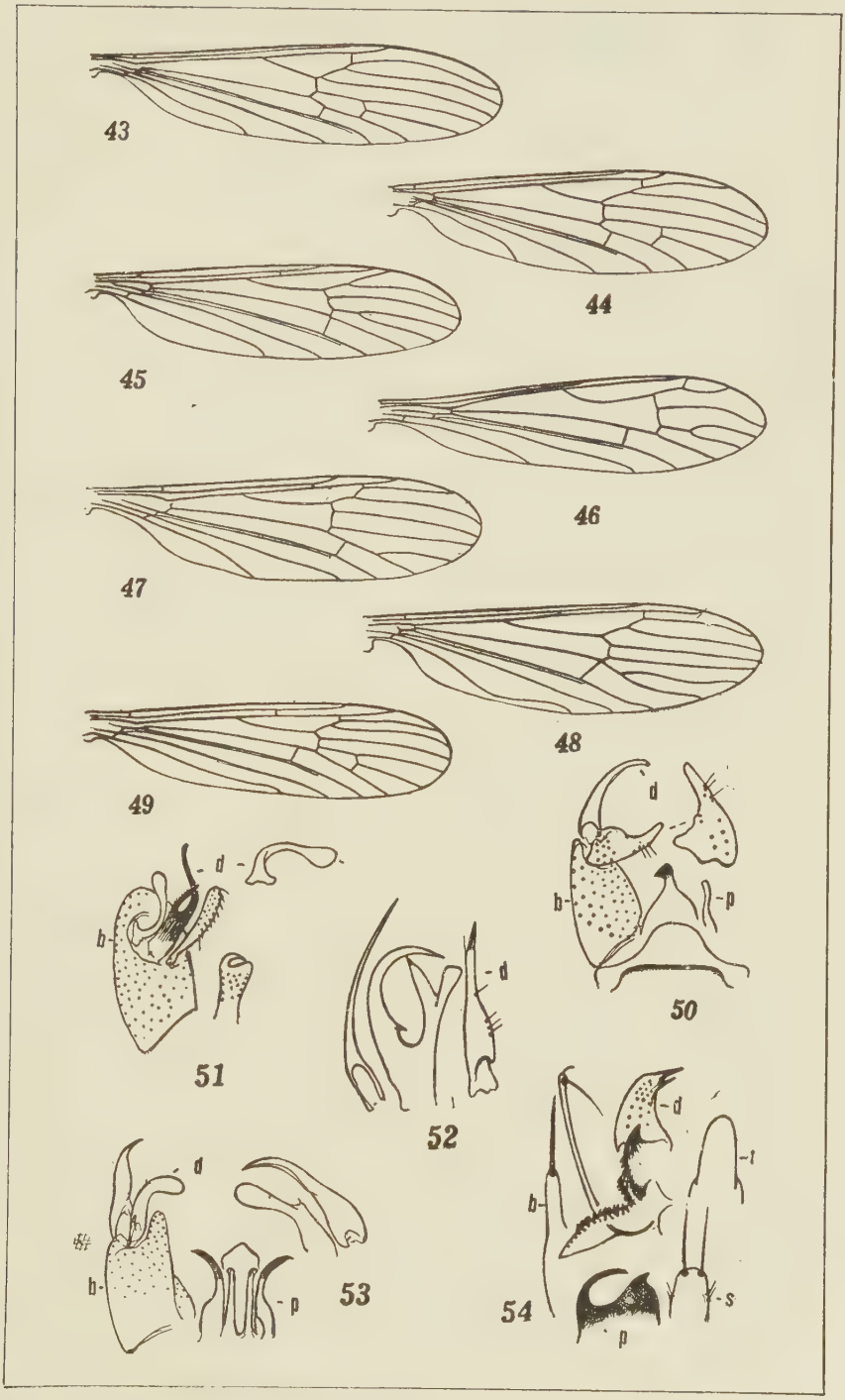


PLATE 5.

AN IRON-FREE BETA-RAY SPECTROMETER FOR ELECTRON-ELECTRON COINCIDENCES *

By JOSE O. JULIANO
Philippine Atomic Energy Commission, Manila

TWO PLATES AND THIRTEEN TEXT FIGURES

INTRODUCTION

As the knowledge of nuclear energy levels advances each year the need for coincidence spectrometers becomes more and more apparent. A state has been reached where mere numerology of the transitions involved, as determined from conversion-electron energies and gamma-ray spectra, is often not of much help in the final analysis of the problem. This is especially true when extremely complex spectra are encountered, a common occurrence in the heavy-element region. In cases in which moderate resolution is sufficient, measurement of gamma-gamma coincidences has been very useful and is still the most widely used method. However, for more complicated nuclides, higher-resolution instruments are needed to select with confidence only the transitions whose energies are being studied. The obvious resort is to use the monoenergetic conversion-electrons associated with the transitions and to find out which of these are in coincidence. This method has been used to advantage and electron-gamma coincidence spectrometers have been built. However, in extreme cases (i.e., with very complicated gamma spectra where so many transitions occur in the same energy range that the gamma spectrum appears like a continuous distribution) there is no other choice but to use an electron-electron coincidence spectrometer. This is in spite of the lower transmissions inherent in beta-ray spectrometers as compared to gamma-ray analyzers, and the fact that the number of events may be further reduced by the conversion coefficients of the transitions being studied which are usually

* A preliminary report of this investigation was made under UCRL–3733 (unpublished) of the University of California where the experimental work was done with the support of the United States Atomic Energy Commission. The author takes this opportunity to express his gratitude to the University of California Lawrence Radiation Laboratory for permission to reproduce photographs of the instrument (Plates 1 and 2), and for valuable technical aid given him during the construction of the instrument.

small for high-energy transitions. With these problems in mind, it is expected that the use of electron-electron coincidence spectrometers would also have its own serious limitations. However, it should be a powerful tool when used in conjunction with the conventional instruments of analysis.

Numerous types of spectrometers have been built and described in the literature,[1-6] both for standard electron spectroscopy and for coincidence spectroscopy using electron-electron or electron-gamma techniques; hence no review is given in this report. Each type of spectrometer has its own merits as to resolution, transmission, method of data gathering, and initial cost; yet no single type can be said to be superior to the rest. The characteristics of various spectrometers have already been discussed in detail [3] and what is generally considered desirable is a spectrometer of high resolution and transmission.

It was decided to build two thin-lens iron-free beta-ray spectrometers joined back-to-back at their source ends for electron-electron coincidence spectroscopy. The finished instrument and its control panel are shown in Plates 1 and 2. In this fashion two different energy conversion lines or beta particles can be focused and independently counted on either side of the instrument and the pulses fed into a regular coincidence circuit. For increased flexibility, the instrument was also designed to be easily converted into a gamma-electron coincidence spectrometer by placing a canned NaI (Tl) crystal at the back of the source through a long iron pipe and using one of the two spectrometers as a regular beta-ray spectrometer.

During the construction and development of this instrument a new approach in fast coincidence techniques was developed, namely the "time-to-height converter" method of analysis.[7, 8] Although not in the original plans, this innovation was used and incorporated in the coincidence circuit with much success.

[1] Persico, E., and C. Geoffrion. Rev. Sci. Instr. 21 (1950) 945.

[2] Verster, N. F. Progress in Nuclear Physics [Academic Press, New York 2 (1952) 1.]

[3] Siegbahn, K., ed. Beta and Gamma-Ray Spectroscopy (North-Holland Publ. Co., Amsterdam, 1955).

[4] Siegbahn, K. Arkiv Fysik 4 (1952) 223.

[5] Pratt, Boley, and Nichols. Rev. Sci. Instr. 26 (1951) 92.

[6] Thomas, D. A. The Vanderbilt Beta-Ray Spectrometer and the Radioactive Decay of Tin–113. USAEC ORO–64, October, 1952.

[7] Moody, N. F. Electronic Eng. 24 (1952) 289.

[8] Weber, Johnstone, and Cranberg. Rev. Sci. Instr. 27 (1956) 166.

Multipolarities of electromagnetic transitions are usually determined from their conversion-electron coefficients, relative intensities of their conversion electrons, angular correlation of the emitted particles and/or gamma rays, or if measurable, the lifetimes of the states.[9] With this coincidence-electron spectrometer it is hoped that uncertainties in the energy levels of excited nuclides can be explained, not only by reliable coincidence measurements but also by giving limits to the lifetime of the state being investigated and, in one way or another, assigning the multipolarities to the transitions.

DESCRIPTION OF THE INSTRUMENT

Spectrometer proper.—The vacuum tank, the two magnetic coils, the two trimmer coils, and the Helmholtz coils were all supported by a welded frame of aluminum-alloy angles and channels 50 inches long, 27 inches wide, and 62 inches high. The magnets were suspended from the top by a centrally located 1-inch-thick aluminum sheet, and the vacuum chamber was supported by brass screws attached to the vertical half-inch-thick sheets.

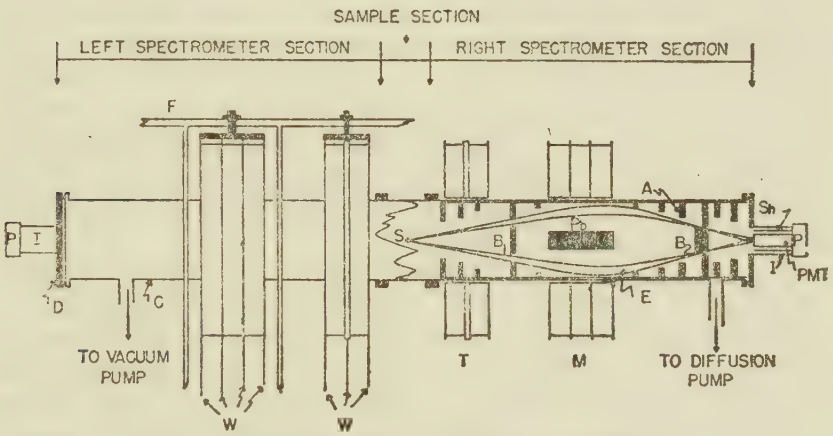


FIG. 1. Longitudinal section of the electron spectrometer.

The vacuum chamber was made of rolled 0.125-inch-thick 61-S-T-aluminum-alloy sheet shaped into a cylinder with a mean diameter of 9.6 inches and aluminum-welded together at the edges. Its over-all length was 200 cm and it was divided into three sections: the left spectrometer tank, the sample or source tank located at the center, and the right spectrometer tank. (Fig. 1.) Such a division made adjustments easier, and

[9] Siegahn, K., ed. Beta and Gamma-Ray Spectroscopy (1955).

in case of contamination only the source tank would have to be replaced. These three parts were joined together by nonmagnetic stainless steel bolts and nuts, and with the use of rubber gaskets and "Celvacene" heavy vacuum grease,[10] a vacuum of 10^{-5} mm of mercury was easily attained. The left and right tanks, which were two independent spectrometer chambers, were supported at each end by three brass screws mounted on the main stand of the instrument. This permitted adjustments to be made on the position of the vacuum tank in relation to the magnetic field.

Discs of half-inch-thick brass were bolted with rubber gaskets to each end of the spectrometer and to these were attached the detectors to be used in the experiment. There were three types of end plates corresponding to the three detectors that can be used with the spectrometer. Thus, by changing endplates, a different counter can be used with the spectrometer.

The sample is introduced through an air-lock assembly located at the side of the center section by a highly polished nonmagnetic stainless steel probe 0.77 inch in diameter and 12.4 inches long. To insure the safety of the worker, a lucite glove-box was clamped to the center section of the spectrometer at the source entrance. The sources were mounted onto the probe inside this box which was connected to the building ventilation system through an air filter. This arrangement reduced the danger of spilling or of dropping the sample, especially with sources mounted on thin plastic films which easily break when a gush of air hits them or simply become brittle and crack after a while.

Vacuum system.—The vacuum equipment of the spectrometer consisted of a Model KC–5 Kinney[11] vacuum pump as the roughing pump and an oil-diffusion pump with a Duo-Seal[12] vacuum pump as the fore pump. Since no magnetic parts were allowed within a radius of two meters from the instrument, the diffusion pump had to be built out of nonmagnetic stainless steel in order that it could be attached directly to the vacuum chamber. The barrel was 14.5 inches long and 4.0 inches in diameter. The cooling tube was a 0.25-inch-diameter copper tube soft-soldered around the outside of the barrel with

[10] Made by Distillation Products Industries, Division of Eastman Kodak Co., Rochester, New York, U. S. A.

[11] Made by Kinney Manufacturing Division, Boston, Mass., U.S.A.

[12] Made by W. M. Welch Scientific Co., Chicago 20, Illinois, U. S. A.

a pitch of 0.6 inch. Laboratory tap water at the rate of 1 gpm was used to cool the diffusion pump. The jets for the pump were obtained from commercial diffusion pumps and Distillation Products' No. 20 diffusion oil was used in the pump. Since the installation of the spectrometer no maintenance of the vacuum system had been necessary.

The spectrometer tank can be pumped down to 10^{-5} mm of mercury from atmospheric pressure in about an hour. The building vacuum outlets were used for preliminary evacuation of air, i.e., from 1 atmosphere to about 2 inches of mercury and then the roughing pump carried it down further to about 80 μ. It has been the practice to use the diffusion pump with the roughing pump for pressures of 80 μ to 20 μ. From 20 μ down, the diffusion pump was used alone. Tank vacuum was measured by a type–501 NRC–thermocouple vacuum gauge [13] and an RCA–1949 ion gauge.

It was observed that some oil vapor from the diffusion pump escaped into the spectrometer chamber where it finally condensed. To prevent this, a double Venetian-blind type of baffle, one section on top of the other, was placed between the diffusion pump and the vacuum chamber as an oil trap. Originally, copper tubes were soldered on the trap's wall for cooling either by liquid freon or by tap water. Further cooling of the trap was found unnecessary however, for air cooling was sufficient. The installation of the oil trap was found to hamper the pumping capacity of the diffusion pump only slightly, but it completely prevented the escape of the oil vapors from the diffusion pump into the spectrometer proper.

Baffle system.—Four types of baffles were used for different purposes (Plate 2). The first was 30.3 inches from the source and accepted a solid angle between 7° and 10°. This was made of a 0.5-inch-thick aluminum disc. The design was based on the calculations by Pratt, et al.[14] on the solid angle giving the highest transmission possible for a resolution of 2 per cent. Eight baffles, all made of aluminum, were placed between the first and the ring-focusing baffles. Their function was to reduce the amount of scattered electrons hitting the detector. At the axis of the spectrometer was centrally placed a lead cylinder 8 inches long and 2 inches in diameter enclosed in a

[13] Made by National Research Corporation, Equipment Division, Newton Highlands 61, Mass., U. S. A.

[14] Pratt, Boley, and Nichols. Rev. Sci. Instr. 26 (1951) 92.

0.125-inch-brass shell. This was sufficient to stop most of the gamma rays of the source from hitting the detectors. A ring-focusing baffle was mounted 6 inches from the detector where the constriction of the electron beam was determined by photographic method to be present. All these baffles were mounted on three brass rods by brass screws so that they can easily be removed and placed back into the spectrometer chamber by just simply pulling or pushing the whole baffle assembly. This was found to be very convenient because it was difficult to reach the end of the spectrometer close to the sample from the detector end, a distance of 100 cm and a diameter of only 9.6 inches. In addition, it simplified the changing of the spectrometer from an electron-electron coincidence spectrometer to an electron-gamma coincidence spectrometer or vice versa.

Main magnetic coils.—The main magnets were designed to focus electrons up to energies of about 3 Mev. With an average radius of 7.87 inches for the magnetic coil, and a focal length of 10 inches, and using the formulas of Deutsch, et al.,[15] 34,950 ampere-turns would be required to focus 3-Mev electrons. The main magnet was constructed with an outside diameter of 20.65 inches and an inside diameter of 10.75 inches. To facilitate cooling it was divided into three sections, each 1.75 inches wide and 5 inches thick. The spool was made of brass and the inner bottom and sides were covered with a layer of 0.012-inchsilicone-bonded glass cloth before No. 11 AWG triple-formvar-coated copper wires were wound at random simultaneously on the three sections. Approximately 950 turns were wound per section of the magnet with a resistance of 4.94 ohms per section and a total resistance for all sections of 14.82 ohms. Thus a total of 2.2 kw was required from the 5-kw amplidyne generator to focus 3-Mev electrons, which left enough power for the trimmer coil.

A tap was made on the magnet coil after winding about 790 turns in each section, or more accurately, 3.88-ohm resistance per section. This was advantageous for cases where electron energies of about 1 or 2 Mev were studied since the magnet coil was thinner and the danger of inhomogeneity of the magnetic field was less acute. However, the amplidyne generator had to supply a power of 2.6 kw instead to focus the 3-Mev electrons if only 790 turns were used. All in all there were three terminals: terminal connection 1 (the common lead),

[15] Rev. Sci. Instr. 15 (1944) 178.

terminal connection 2 (3.88 ohms per section), and terminal connection 3 (4.94 ohms per section). In this investigation only the 3.88-ohm part of the magnet was used which was quite sufficient to focus electrons as energetic as 2 Mev. For very-high-energy electrons, which may be studied in the future, the 4.94-ohm section could be used. A simplified drawing of the main magnet is shown in Figure 2.

During the winding of the copper wires, No. 30 iron-constantan thermocouple wire wrapped with a double thickness of glass fiber was imbedded in the center of each section after half of the wire length had been wound. The wire was then connected to the temperature-protection relays of the power supply. The small amount of iron in these wires was not enough to distort the magnetic field of the spectrometer.

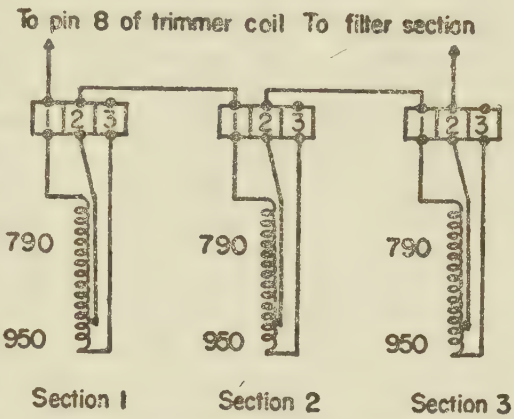


FIG. 2. Simplified wiring diagram of the main magnet coils.

On both sides of the spool and sandwiched between the three sections, horseshoe shaped 0.25-inch-diameter copper tubes for water cooling purposes were soldered to the brass plates of the magnet 0.437 inch apart. There were four sets of seven tubes per magnet. Each tube was continuous and independent so that in case one tube got plugged only that single tube would be affected leaving the rest functioning.

The coils were wrapped outside with a layer of half-lapped glass tape, and the whole magnet was vacuum-impregnated with silicone varnish and baked in the oven. The total weight per magnet amounted to 450 lbs. A high-potential test of 1,500 volts from coil to ground was applied to the magnet coils to check them for current leaks before they were used.

Magnetic trimmer coils.—In instruments of this type it has always been the objective to make the two joined-spectrometers independent of each other; this means that the magnetic field of one should not interfere with that of the other. The

conversion-electron peak should be a function only of the current in the spectrometer where it is being detected, and not a function of the current intensity of the other spectrometer. This is important, because one would always be detecting a certain particular energy while the whole beta spectrum would be measured with the other spectrometer. If the spectrometer were made of iron, this corrective measure would not be necessary but it must be considered for this nonferrous instrument. There are two ways of solving this problem. One is to increase (or decrease, as the case may be) the magnetic field of the gate side to compensate for the shift in the conversion-electron peak as the magnetic field varies on the other side. Although compensation is usually automatic, it is inconvenient because the current-calibration factor would be a function of the power supplied to the opposite magnet. Another approach, the one used in this report, was to place compensating or "trimmer" coils between the two main magnets with the hope that they will minimize these undesirable disturbances in the magnetic-field distribution as much as possible without distorting the conversion-electron line shape. Since the exact number of ampere turns needed by the trimmer coils to neutralize the effect of the main magnet on the other side of the instrument was not known, the trimmer coils were designed so that one can vary the number of turns to be used from 25 to 1,100 turns simply by connecting the proper tapleads located at the outside of the coils. A simplified drawing is given in Fig. 3.

The trimmer coils were made up of two sections, one had a fixed number of turns and the other could be tapped at different parts of the coil. The spool was made of brass with an outside diameter of 20.6 inches, an inside diameter of 10.75 inches, a thickness of 5.25 inches and an inside channel width of 1.3 inches per section. Cooling was accomplished by passing water through copper tubes soft-soldered to both sides of the spool as well as through the 0.5-inch-thick center cavity between the two sections. The water inlet was at the bottom and the outlet was at the top of the coil. The same cooling water was supplied to the trimmer and main magnet coils.

Section 1 of the trimmer coil was wound with 550 turns of No. 9 AWG heavy formvar-coated copper wire after the inside of the spools were covered with glass tape and 12-mil combination electron "300" insulation. For section two of the coil the same procedure was followed, except that taps were made at

0, 25, 50, 125, 275, and 550 turns by phos-copper -soldering ⅜-inch wide No. 18 B. & S. gage copper strips to the wire. These leads were wrapped with tape and connected to the terminal strip located outside the coil. After the coils were wound, they were wrapped on the outside with a half lap of glass tape, vacuum-impregnated with "Dolph-B.C. 307" varnish, and then baked in an oven at 150°C for 8 hours.

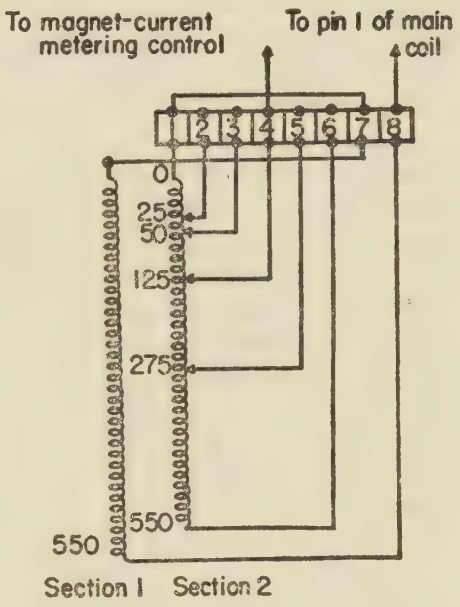


FIG. 3. Simplified wiring diagram of the trimmer coils.

Cooling system.—Because a large amount of magnet current is needed to focus the high-energy electrons, air-cooling alone is not sufficient to maintain the temperature within the optimum range. The temperature may reach a point where it may ruin the magnet, especially when focusing high-energy electrons (2 Mev). For example, a current of 10 amp in a magnet without water-cooling increased the magnet temperature about 2° per minute; hence, after 20 minutes destructive burning of the coil may occur. When the coils were cooled with water, a current of 15 amp in the coils for several hours caused an increase of only 1°C in the magnet temperature. The magnets were cooled by passing through the cooling tubes "Calgon"[16] treated water passed through a "Micro-Kleen" filter[17] at a rate of 4 gpm. Water thus treated is used at the University of California Radiation Laboratory for cooling magnets of the bevatron, cyclotron, and other accelerators. After use, this water is cooled, its pH adjusted, treated and recirculated

[16] Sodium hexametaphosphate, made by Calgon, Inc., 1943 Hagan Bldg., Pittsburg, Pa., U. S. A.

[17] Model 3AXB2, manufactured by Cuno Engineering Corp., Meriden, Conn., U. S. A.

through the system. To cool the machines adequately with a smaller volume of water, cooling of the water to about 5°C is planned for the future.

The pressure of the water before entering the filters was 40 psig, but dropped to 10 psig, after passing through the filters and magnet-cooling coils. To protect the coils in case of water failure, a "Shur-Flo"[18] automatic interlock-relay which turned off the magnet current when the water-flow fell below 4 gpm, was placed in each of the magnet water-cooling systems.

Magnet power supply.—The two spectrometer units had similar independent magnet power supplies so that the following description would apply to either of the two spectrometer power supplies. A block diagram of the magnet current supply is shown in Fig. 4. The magnets obtained their power from a General Electric amplidyne generator, model 5BY1543, which delivered 20 amp at 250v. This was belt-driven by a Fairbanks-Morse induction motor type QZK, which was rated at 2,890 rpm with a full load. Three of the four amplidyne windings were used with the first two connected in series. The three windings were designated respectively as the reference field, voltage control field, and the anti-hunt field windings. The dc output of the amplidyne was filtered by a filter section to remove some of the ripples present that were caused by the noise from the brushes and armature of the generator. In series with the dc output was the magnet-metering section where a 0.08000 ± 0.00004-ohm manganin temperature-independent-type resistor and a 0.1000 ± 0.0001-ohm precision-wire-wound resistor were used to measure the current going to the magnet. A Rubicon No. 2780 potentiometer standardized against an Epply No. 100 standard cell using a Leeds and Northrup Type–2420C galvanometer determined the potential drop across the manganin resistor. A direct-reading ammeter with ranges 0 to 1, 0 to 10, and 0 to 25 amp was connected to the 0.1000-ohm resistor. After being filtered and measured, the current proceeded to the magnets. The main and trimmer coils were connected in series and with opposing magnetic fields.

To stabilize the power in the magnetic coils, the potential drop across both the 0.08000- and the 0.1000-ohm resistors of

[18] Made by Hays Manufacturing Co., Erie, Pa., U.S.A.

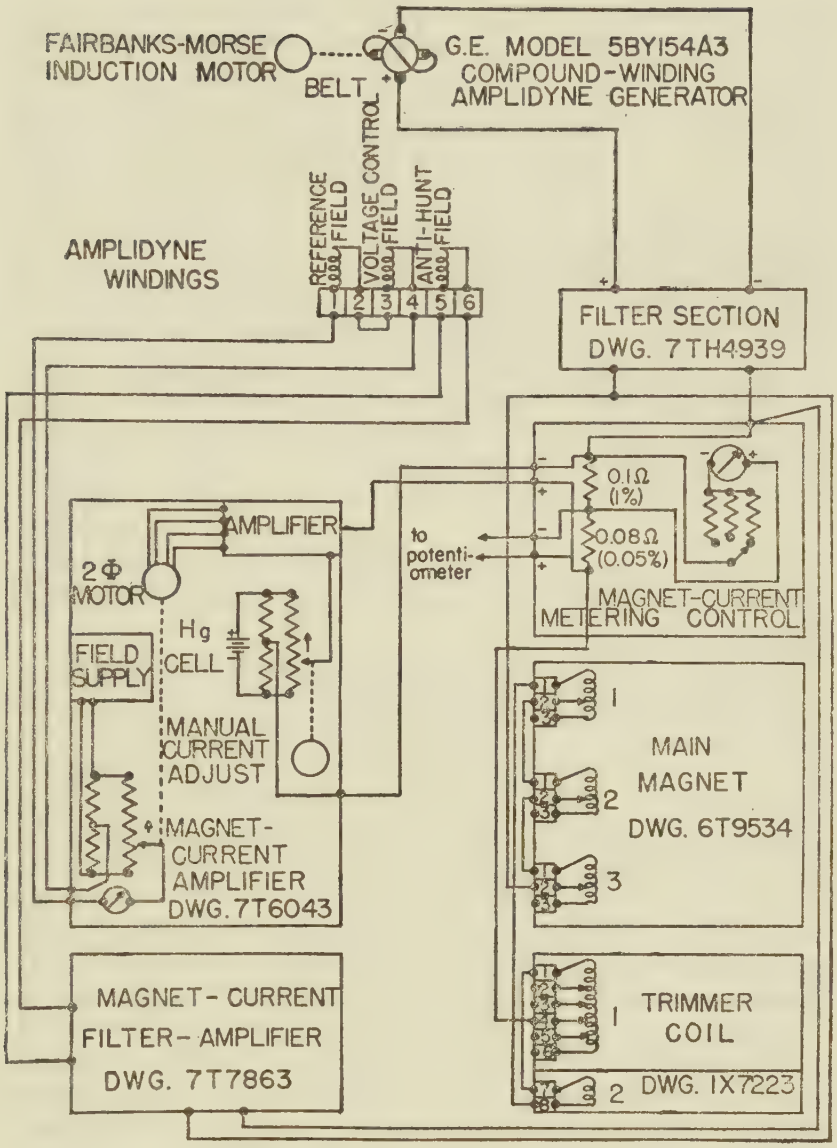


Fig. 4. Magnet-current block diagram.

the magnet-metering section was fed into the magnet-current amplifier where it was continuously compared to the potential supplied by four mercury cells spot-welded together. The amount of reference potential from the mercury cells was

determined by connecting a 5000-ohm Helipot resistor to the manual current-control. Any excess unbalanced current between the reference potential and the potential drop across the resistors of the magnet-metering section was detected and amplified by a Leeds and Northrup amplifier. The amplifier sends correcting signals to a 2-phase motor which was connected through a clutch to a 100-ohm Helipot resistor that controlled the field current being fed to the reference and voltage-control amplidyne windings. Hence, any increase or decrease in the current output of the amplidyne was detected by the amplifier and resulted in the decrease or increase of the amplidyne field current until the normal current output was obtained. With this arrangement, variations in current of up to 9 cps were corrected. For fluctuations of from 9 to 60 cps the filter-amplifier section of the dc power supply to the magnet compensated for within a second. In this setup no precaution was deemed necessary for stray pulses greater than 60 cps because such high-frequency noises were essentially short-circuited by the large capacitors located in the magnet-current filter-amplifier.

Examination of this circuit which consisted of the amplidyne, magnetic coils, and damping condensers, showed that a resonant frequency of 9 cps was present along with a 60 cps noise and the system was not at all stable. To remove both the weak 60-cycle and the strong 9-cycle disturbances in the amplidyne output, a part of the dc output of the amplidyne with its 60-cycle noise was tapped at the filter section and inverted by a transformer. When this inverted 60-cycle signal was mixed with the regular field-current supply, the original 60-cycle noise was cancelled, leaving only the strong 9-cycle resonance. This was amplified at the filter amplifier of the magnet-current supply and fed into the anti-hunt field-winding of the amplidyne 180° out of phase by inverting the leads. With this arrangement, the resonant-frequency noise and the 60-cycle signal picked up from the nearby ac cables were eliminated.

A test for stability was made by connecting the potentiometer output to a Leeds and Northrup Speedomax recorder. With a current of 4 amp, enough to focus a 600-kev electron, the noise or ripple was 0.25 mv, equivalent to 3 ma. This was better than 1 part in 1,000 current control. After the magnet was

operated for 17 hours, the observed shift was 25 ma, which was a current regulation of 6 parts in 1,000. Most of the power shift occurred during the first hour when the magnet was still cold. Thereafter a current regulation of 3 parts per 1,000 was achieved. No marked increase in temperature was noted from the thermocouples in the magnet.

Earth's-field compensating-coils.—For air-core spectrometers with long electron paths like this one, transverse components of the earth's magnetic field should be cancelled out especially for low-energy electrons. If no compensation was made for this factor, the transmission drops down as the electron energy decreases because the earth's field pulls the electrons out of focus. In addition, deviations in the current-calibration constant were observed. It was decided to follow Haynes and Wedding's [19] method in designing the rectangular coils (Helmholtz-pair coils) to neutralize the earth's field inside the spectrometer.

Two vertical frames, each 129 inches long and 36.5 inches high and two horizontal frames each 139 inches long and 26.5 inches high, were made from 1 by 0.5 inch aluminum-alloy channel. These were attached to the framework of the spectrometer with brass screws so that the vacuum chamber was boxed by the four rectangular frames. On each of the vertical frames was wound in series 125 turns of No. 26 Formex [20] copper wire coated with heavy "Formvar." This was the horizontal-component field coil. In each of the horizontal frames, which was the vertical component, was wound 250 turns of No. 26 Formex copper wire. Power for these coils was obtained from two standard regulated power supplies.

To almost completely neutralize the magnetic-field effects on the low-energy electrons, the Helmholtz coils should be supplied with precise amounts of current. An ordinary magnetic compass was not sufficient to detect the null-point while the current intensities of the horizontal and vertical coils were varied. So a 5-inch RCA–5 CPIA cathode-ray tube with a variable control for the electron energy produced by the electron gun was placed at the center and along the axis of the spectrometer chamber. It was assumed that when electrons of about 800 kev were accelerated by the electron gun, they were not affected by the

[19] Rev. Sci. Instr. 22 (1951) 97.

[20] Made by Formex Wire Company, Anaheim, California, U.S.A.

earth's field; hence, their luminescent spot on the cathode-tube screen was made the fiducial mark for a cancellation of the earth's magnetic field at the center of the chamber. The accelerating potential was decreased to a few kev and the bright spot was displaced about 1.5 cm. When the power supplied to the Helmholtz coils was adjusted the bright spot was brought back to its original position. With this current setting, the energy of the electron was again varied from 800 kev to a value so low that the luminescent spot began to spread but no noticeable shirt in its position was observed. The current required was 75.8 ma and 57.8 ma for the vertical and horizontal coils respectively.

Electron detectors.—For counting electrons a highly polished circular disc of Livermore plastic-scintillator [21] 0.5 inch diameter and ⅛ inch thick was optically joined by Riggs' bonding agent R–313 [22] to an RCA–6655 photomultiplier-tube window. The photomultiplier tube was shielded from the magnetic field by a mu-metal shell; and an iron tube screwed to the end-plate of the spectrometer chamber and the cathode-follower housing provided the necessary support as well as the light protection. For cases where electrons of less than 60 kev were being studied, anthracene crystals of the same size were used instead of the plastic scintillators. Usually a 1,000-volt potential was applied to the photomultiplier tubes in all the experiments.

In experiments where low-energy electron were being studied and no coincidence measurements were to be made, the end plate of the spectrometer containing the side-window G-M counter was used. The G-M counters were made of brass and the thin plastic windows were supported by grids.[23] VYNS–3 films [24] were used as counter windows, which allowed the transmission of 1-kev conversion electrons. A mixture of

[21] This plastic scintillator is composed of styrene with 2.5 per cent terphenyl, 0.03 per cent tetraphenyl butadiene, and 0.01 per cent zinc stearate.

[22] Manufactured by Carl H. Biggs Co., 2255 Barry Ave., Los Angeles 14, California, U. S. A.

[23] Passel, T. O. Internal Conversion of Gamma Radiation in the L-Subshells. University of California Radiation Laboratory Unclassified Report UCRL–2528, 1954. (Unpublished Thesis)

[24] Pate, B. D., and L. Yaffe. Canadian Jour. Chem. 33 (1955) 15.

90 per cent argon and 10 per cent ethylene was used in the counter.

Coincidence circuit.—The negative pulses of the "start" side of the coincidence circuit were sent from the photomultiplier tubes through a pre-amplifier and cathode follower to a bank, usually three, of Hewlett-Packard 460A [25] wide-band amplifiers (modified). After the first wide-band amplifier, the output pulses, still negative, were branched. One part went to a UCRL linear amplifier and then to a UCRL–1024 scaler, while the other part was further amplified by more wide-band amplifiers until all the pulses were saturated. Finally, the negative output of the last Hewlett-Packard 460A unit was fed into the "start" input of the time-to-height converter. (Fig. 5)

On the other hand, the pulses from the "stop" side of the circuit, after being amplified by a 460A wide-band amplifier and a 460B wide-band amplifier proceeded to a delay box consisting of measured lengths of RG–63/U cables.[26] From the delay box the pulses, now positive, were fed to another 460B amplifier where they were further amplified and converted to negative pulses. The output was then fed to the "stop" input of the time-to-height converter, whose output was proportional to the time interval between the "start" and "stop" pulses.

Because the output of the time-to-height converter was a negative pulse, it had to be converted into a type that can be used in the 50-channel pulse-height analyzer. Thus, the output of the time-to-height converter was attenuated and then fed into a Los Alamos DD2 linear amplifier [27] whose output was a positive short pulse. This pulse was sent to the pulse shaper, where it was stretched to about 10 μsec, and fed into the input of the 50-channel pulse-height analyzer.[28]

In order to reduce the number of chance coincidences, a slow-coincidence circuit was also used. One of the outputs of the UCRL linear amplifier on the "stop" side of the circuit

[25] Hewlett-Packard Co., Palo Alto, California, U. S. A.

[26] Strominger, D. Experimental Study of Nuclear Isomers in the Millimicrosecond Lifetime Range. University of California Radiation Laboratory Unclassified Report UCRL–3374, 1956. (Unpublished Thesis)

[27] Johnstone, C. W. Nucleonics 11 (1953) 36.

[28] Ghiorso, A., and A. E. Larsch in Chemistry Division Quarterly Report, UCRL–2647 (July, 1954)

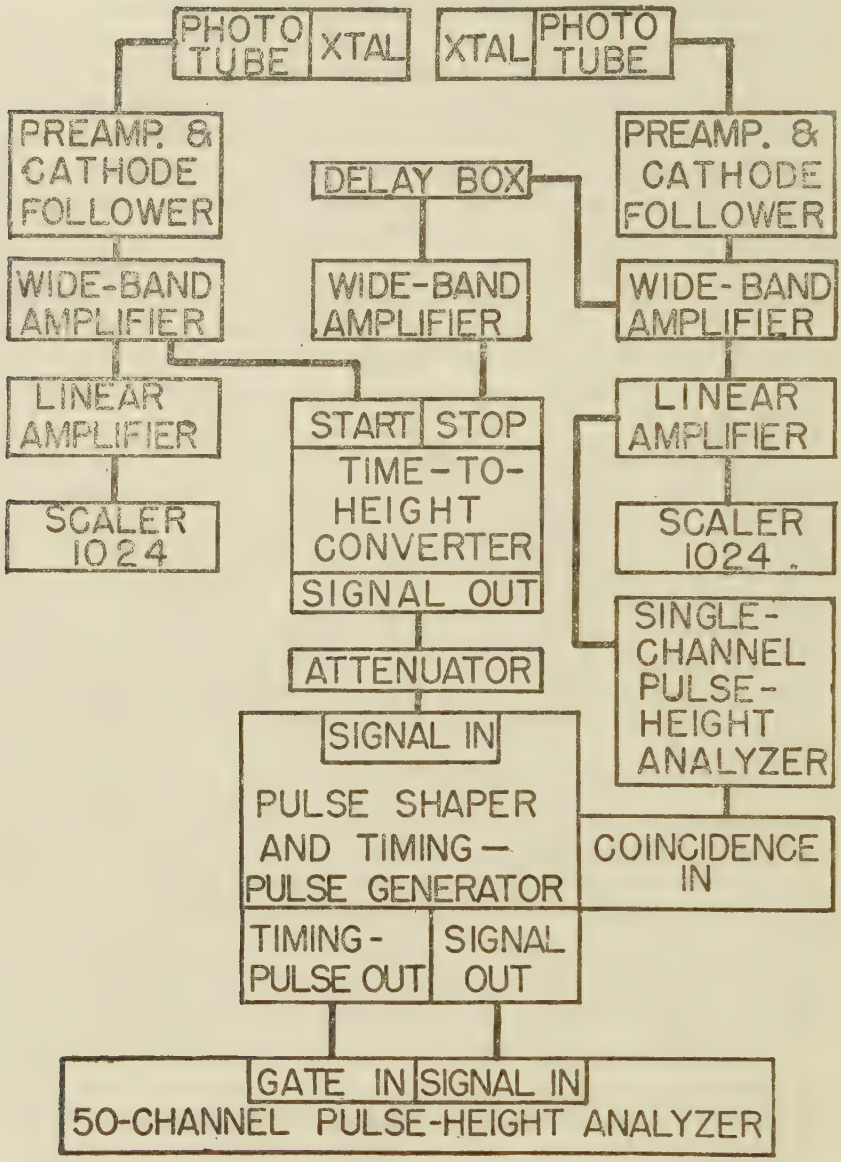


FIG. 5. Fast-slow coincidence-circuit

was connected to the input of a Los Alamos single-channel pulse-height analyzer. The pulses above noise from the analyzer were fed into the "gate" part of the slow triple-coincidence cir-

cuit (the pulse shaper and timing-pulse generator sections in particular). Here a part of the signal or "start" pulse triggers a multivibrator which sends a pulse to the triple-coincidence circuit. Only when the pulses from the start pulse and the gate pulse arrive within the resolving time of the circuit, about 2 μ sec, will a timing pulse be generated. This was used as the gate pulse for the 50-channel pulse-height analyzer.

Sources.—Sources were made by evaporating 5- to 20-λ solutions of the sample on 0.1- to 0.5-mil copper, gold, platinum, or plastic films, depending on the sample and the experiment. These backings were mounted on brass rings 0.5 inch in diameter which were soldered to brass rods that fitted the sample-probe end. From the author's experience, the metal foils were more convenient than the plastic films for there was less danger of charging in the metallic source-backings even if the plastic films were painted liberally with "Aqua-Dag." The effect of the metallic foils on the peak was to broaden its shape (poorer resolution) and to decrease its counting rate (lower transmission). However, these were minor points compared to the ease in the use of metal foils. Nevertheless, for low-energy electrons and for studies of beta-spectrum shapes, thin films have to be used. After different plastic films were tried "VYNS–3" (a polyvinyl-cloride-acetate) was chosen over "Zapon," "Tygon," or "Clear Clad No. 1060."[29] Usually two layers of film with a total thickness of 10 to 20 μ g/cm^2 was used for source backings. VYNS resin, a finely ground white powder, was dissolved in cyclohexanone and the film was made in the manner of Pate and Yaffe.[30]

TESTS ON THE OPERATING CHARACTERISTICS OF THE SPECTROMETER

Ring-focusing-baffle.—After the spectrometer was assembled and a good vacuum was obtained an initial run was made using a 1-mC source of Cs^{137} procured from the Oak Ridge National Laboratory and evaporated on a 1-mil copper foil. The plastic scintillator was masked by a 0.4 inch thick aluminum disc having a cone-shaped bore at the center measuring 3 mm at the smallest diameter. The side with the smaller opening was placed close to the scintillator. With only the first aluminum

[29] Passel, op. cit.
[30] Loc. cit.

baffle and the center lead shield, the counting rate of the Cs^{137} 625-kev conversion-electron peak was maximized by moving the coils. The purpose of this run was to determine the current necessary to focus the conversion electrons of Cs^{137} so that they would hit the scintillators located at the ends of the spectrometer chamber. Then with the same current setting, a Kodak No-Screen x-ray photographic plate was placed horizontally at the axis of the spectrometer chamber near the detector end and exposed for 20 hours to determine approximately the path of the focused electrons and also the region where ring-focusing occurred. The exact position of the ring-focusing region had to be determined and could not be based on the findings of Pratt, et al.[31] because the presence of the trimmer-coils produced a perturbation on the magnetic-field distribution which was not present in the previous investigations. After the expected location of the constriction in the electron path was determined from the above pictures, a series of x-ray plates were exposed at distances 0.25 inch apart in this region. Each plate was exposed for a period of 10 hours with the same sample and current settings. The K- and L-conversion electrons were well defined in all the plates and the position where the K- and L-conversion-electron line widths were smallest and the separation was largest was chosen for the ring-focusing-baffle position (Plate 2, fig. 2). To test the effect of the trimmer coil on the ring-focusing position and, indirectly, the perturbation of the trimmer coil on the main magnet field, a similar experiment was performed without the trimmer coil. Exactly the same results were obtained for both cases, except that a different calibration constant or factor had to be used to focus the same conversion electrons.

From the results of the x-ray photographic determination (Plate 2, fig. 2), an aluminum ring-focusing baffle (Fig. 6) was designed to accept all the electrons of the same energy. The slight noncircular form of the picture was due to the improper position of the film during the exposure which was not quite normal to the longitudinal axis of the spectrometer chamber.

Transmission of the spectrometer.—An absolute determination of the transmission of the coincidence spectrometer was made using a Bi^{207} source which decayed primarily through the

[31] Loc. cit.

569-kev transition. The amount of this transition in the source was 4.15×10^6 dpm and was calculated from the gamma spectrum obtained from the Penco [32] 100-channel pulse-height analyzer using a shelf geometry of 1.29 per cent and a dead-time correcting of 69 per cent. The crystal efficiency curves of Kalkstein and Hollander [33] (using the same NaI (Tl) crystal) were used to calculate the strength of this transition. From the K-conversion coefficient of Wapstra [34] for the 569-kev transition, which was 1.8×10^{-2}, the absolute number of K-conversion electrons for this transition was calculated and compared to the total number of electrons detected for the K-conversion line of the same sample. A transmission of 1.0 per cent was obtained for a resolution of 2.3 per cent which was the transmission expected when this instrument was designed.

The effect of the trimmer coils on the operation of the spectrometer.—With the 624-kev conversion electrons of Cs^{137} as the source a series of spectra were determined using different current intensities in the opposite spectrometer magnet-coil. The results are shown in Fig. 7 for cases where no trimmer coils were used while 0, 6, and 12 amperes were supplied to the opposite spectrometer. Shifting of the peak was observed even for such high-energy conversion electrons. On the other hand, the low-energy conversion-electron lines, like the 37-kev K-conversion-electron peak of Am^{241}, were not only shifted more but they were also distorted in shape and had a very poor resolution.

The compensating power of the trimmer coil was determined by using different number of turns of the coil and it was found that 674 turns maintained a sufficiently fixed calibration constant without any distortion of the spectral line-shape even with 15 amp (enough to focus more than 2-Mev electrons) on the other spectrometer coil. The real test of the trimmer coil was with the 37-kev conversion-electron lines of Am^{241} at different current intensities in the opposite magnet. The result is shown in Fig. 8 and it clearly proves that with the

[32] Model PA–3 made by Pacific Electro-Nuclear Co., Culver City, California, U. S. A.

[33] A Survey of Counting Efficiencies for a 1.5-Inch-High Sodium Iodide (Thallium Activated) Crystal, University of California Radiation Laboratory Report UCRL–2764, 1954.

[34] Arkiv Fysik 7 (1954) 279.

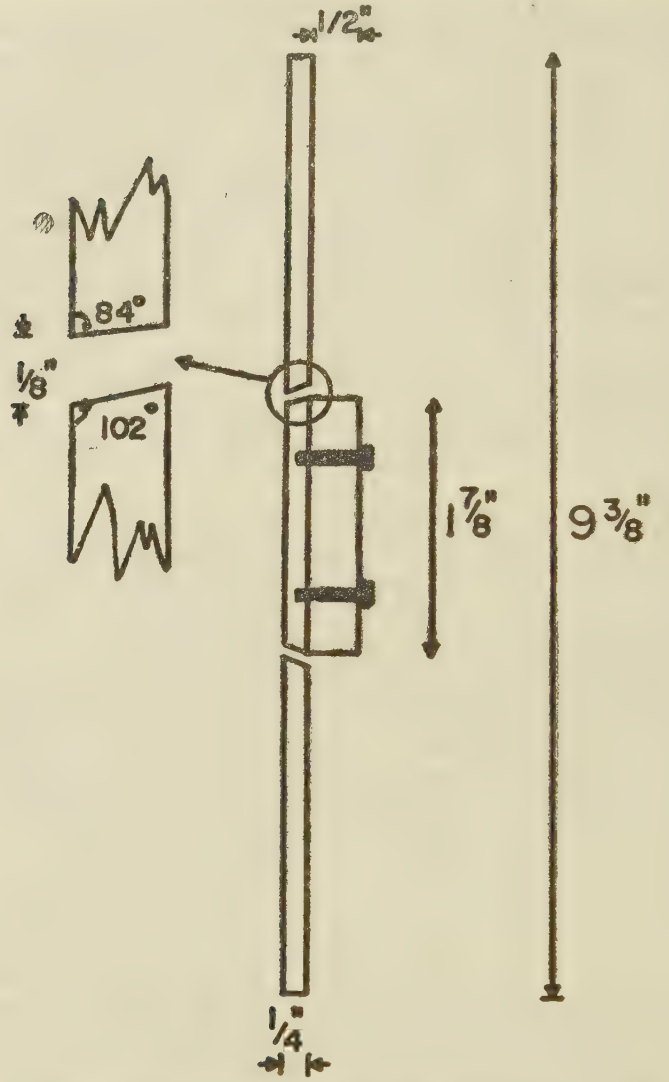


FIG. 6. Dimension of aluminum ring-focusing baffle based on Plate 2, fig. 2.

trimmer coil, shifting and distortion of line-shape had been reduced to such an extent that they can be considered negligible.

Another test made to confirm the neutralizing effect of the trimmer coil was to run the complete beta spectrum of Cs^{137} both with 10 amp and without any current on the opposite spectrometer. All the experimental points fell on the same line and the results are given in Fig. 9.

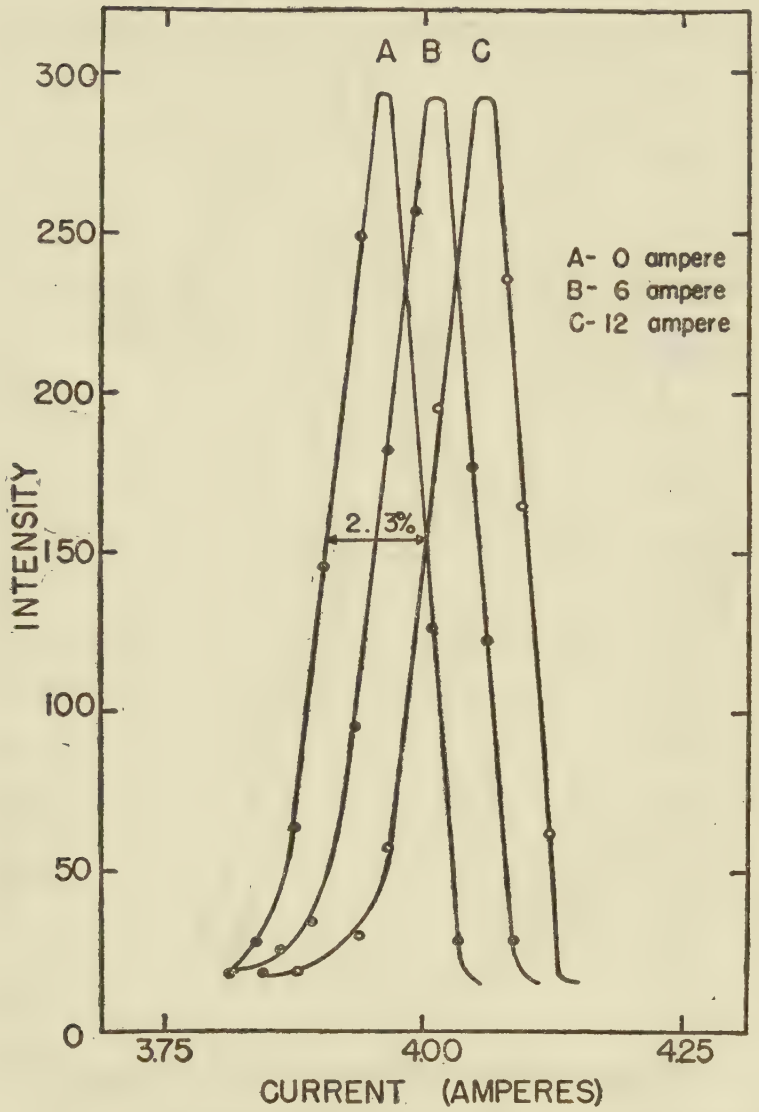


FIG. 7. Effect of the magnetic field on the Cs^{137} K-conversion-electron line of the opposite spectrometer when no trimmer coils were used.

Calibration of the spectrometer.—Each side of the spectrometer was calibrated independently using well-known standards such as Am^{241}, Hg^{203}, Tm^{170}, Cs^{137}, and Bi^{207}. As a further check on the calibrations, measurements were made when the magnet was cold, and these were compared with those obtained after the magnet had been operating for more than an hour.

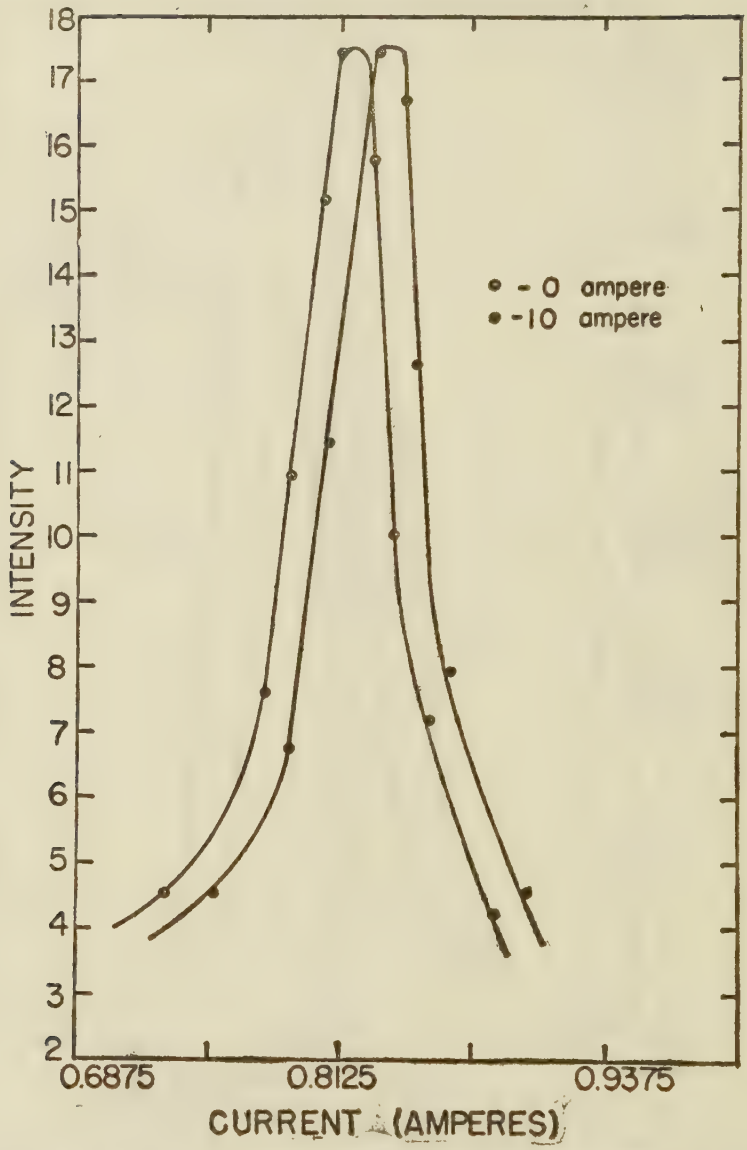


FIG. 8. Effect of the magnetic field of the opposite spectrometer on the L-line 60-Kev transition of Am^{241} with the proper trimmer coils.

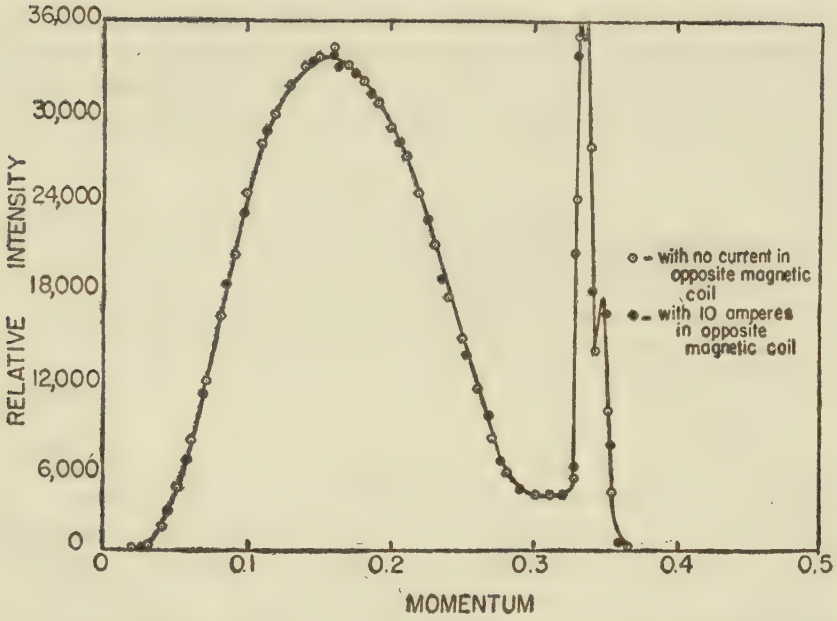


FIG. 9. Compensating effect of the trimmer coils on the opposite spectrometer using the beta spectrum of Cs^{137}.

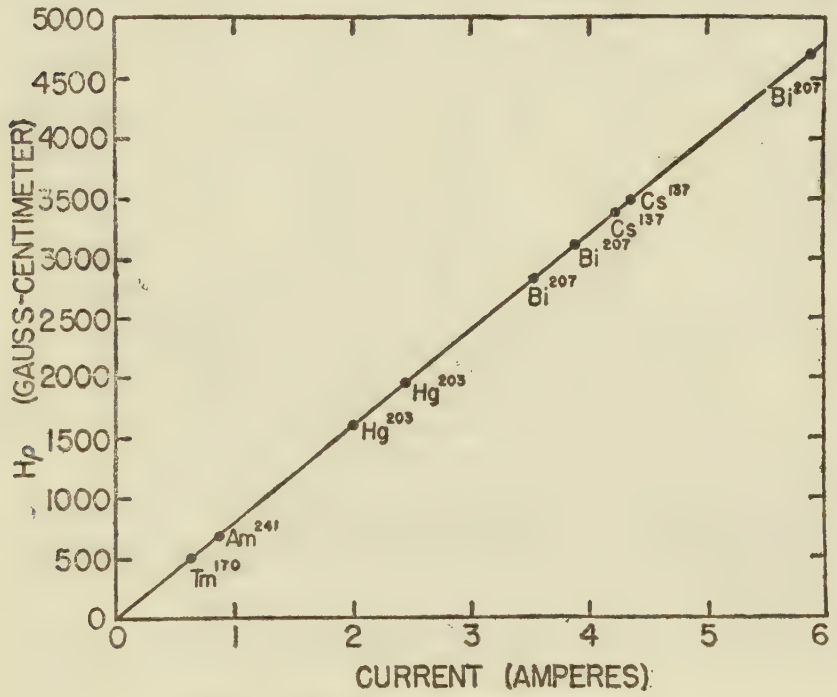


FIG. 10. Calibration curve of the spectrometer.

In addition the spectrometer was also calibrated with the opposite spectrometer turned off and with 16-amp current, the maximum available, supplied to its main magnet coil. In all these, the same calibration constant C was obtained for the equation,

$$H\rho = C1 = (C \times E)/R$$

where $H\rho$ is the magnetic rigidity of the electron being focused by the spectrometer, in gauss-cm;
C is 801.30 gauss-cm per amp;
I is the current being supplied to the main magnet coil in amp;
E is the potential drop across R as determined by a potentiometer in volts; and
R is the manganin resistor known to be precisely 0.08000 ± 0.00004 ohm.

A plot of $H\rho$ in gauss-cm against I in amperes is given in Fig. 10 for some standards which were used to calibrate the instrument and some other conversion electrons whose energies are known with confidence from precision permanent magnet electron spectrographs. All the experimental points fell on a straight line and were reproducible (Table 1). Due to hysteresis, this is impossible for spectrometers made of iron.

TABLE 1.—*Standards used in the calibration of the spectrometer.*

Source	Transition energy (kev)	Conversion shell	Electron energy (kev)	$H\rho$ (gauss-cm)	Current (amp)	C* (gauss-cm/amp)	Reference
Tm^{170}	84.1	K	23.4	521.7	0.651	801.31	(a)
Am^{241}	59.7	L	37.2	662.1	0.826	801.31	(b)
Hg^{203}	279.0	K	193.5	1,617.7	2.019	801.30	(c)
		L	263.7	1,942.2	2.424	801.29	(c)
Cs^{137}	661.6	K	624.21	3,381.3	4.220	801.28	(d)
		L	655.6	3,498.1	4.366	801.39	(d)
Bi^{207}	569.0	K	481.0	2,836.2	3,539	801.30	(e, f)
		L	553.1	3,113.4	3.886	801.28	(e, f)
	1,063.9	K	976.0	4,657.9	5.813	801.32	(d, e)
		L	1,048.0	4,913.2	6.131	801.40	(d, e)

* C=801.30 based on Cs^{137} and Bi^{207}.

[a] Pohm, Lewis, Talboy, and Jensen. Phys. Rev. 95 (1954) 1523.
[b] Day, P. B. Phys. Rev. 97 (1955) 689.
[c] Wapstra, Maeder, Nijh, and Ornstein. Physica 20 (1954) 169.
[d] Siegbahn, K. ed. Beta and Gamma-Ray Spectroscopy (North-Holland Publ. Co., Amsterdam, 1955).
[e] Alburger, D. E., and A. W. Sunyar. Phys. Rev. 99 (1955) 695.
[f] Yavin, A. I., and F. H. Schmidt. Phys. Rev. 100 (1955) 171.

Time-to-height-converter calibration.—The time-to-height converter, to be written from now on as THC, gives a positive pulse output the height of which is proportional to the time difference between the start and stop pulses. However, it was found that at very short times, of the order of millimicroseconds, or at very long time intervals about 5×10^{-7} sec, the linear relationship between the time difference and pulse-height output showed a slight deviation. (Following common usage the term nanosecond,[35] nsec, will be used instead of mμsec in

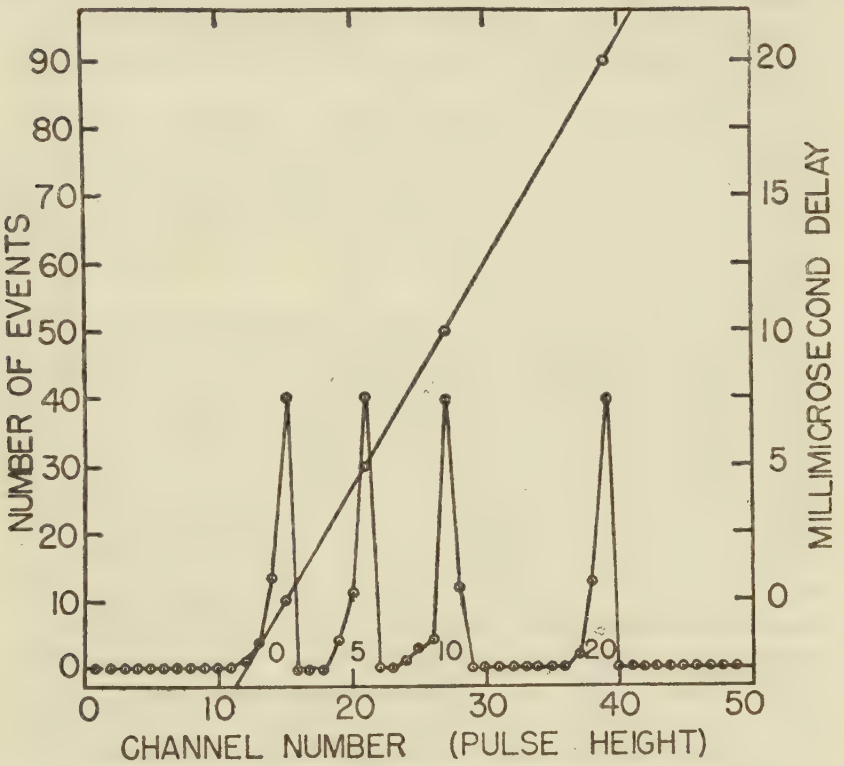


FIG. 11. Calibration curve of the time-to-height converter (THC).

the succeeding pages). To be able to get reliable and accurate results the THC was used in the proper range (the linear part) by introducing an arbitrary fixed delay to the stop-pulse input.

Using the start pulse also as the stop pulse, the THC was

[35] Document UIP6 (1955) of International Union of Pure and Applied Physics, in Physics Today (11) 9 (1956) 23.

calibrated by adding known lengths of cable or known time delays from the delay box to this fixed delay and the height of the output pulse was measured with the 50-channel pulse-height analyzer. A typical calibration curve is given in Fig. 11. By adjusting the amplifier gain a resolution of 0.5 nsec per channel was easily attained. These peaks were usually two channels wide with maximum widths of three channels. For most purposes the THC was used with 2 nsec per channel so that the peak would be more pronounced and easier to detect. This was true when working with very few events in coincidence in the presence of a high background like that of a conversion-electron line riding on top of its continuous beta spectrum.

The main advantage of this type of coincidence analysis is the time element. The whole delay curve is obtained in the same time required to get a point of the curve in the conventional way. This is very helpful for short-lived nuclides. Furthermore, errors due to drifts of the instruments are reduced to a minimum.

Although the peaks were only two channels wide during calibration, they were broader in actual experimental conditions. This can be explained by the statistical fluctuation of electron-transit times in the photomultiplier tube and in the whole circuit itself. One way to solve this problem is to use photomultiplier tubes having 14 stages or more, like the RCA–6810A, where the output can be fed directly into the THC. As long as plastic scintillators or organic scintillators are used, the crystal contribution to the broadening of the peak is negligible; however, for crystals like NaI (Tl) which are slow crystals they would be limiting barriers to the improvement of the resolution.[36] So ordinarily, peaks about eight channels wide at half-height were obtained corresponding to 8 nseconds. When 6BN6-like electronic tubes having more than two grids are commercially made, triple coincidences can be used with the THC.

Electron-electron coincidences in Bi^{207}.—An initial test on the coincidence circuit was made by feeding the K-conversion-electron pulses of the 1063.9-kev transition of Bi^{207} to the

[36] Brown, M. Millimicrosecond Coincidence Instrumentation and its Limitations. University of California Radiation Laboratory, Unclassified Report UCRL–3539, 1956.

start-pulse input of the THC, and the 569-kev transition to the stop-pulse input. The lifetime of the 569-kev state from gamma-gamma coincidence measurements by Gerholm [37] was 9×10^{-11} sec. In other words, for this type of experiment the two transitions can be regarded as prompt and there should be no delay between the two events. The results are given in Fig. 12. The peak width at half-height (resolution) was 7.3 nsec, corresponding to 8.75 channels. A delay between the

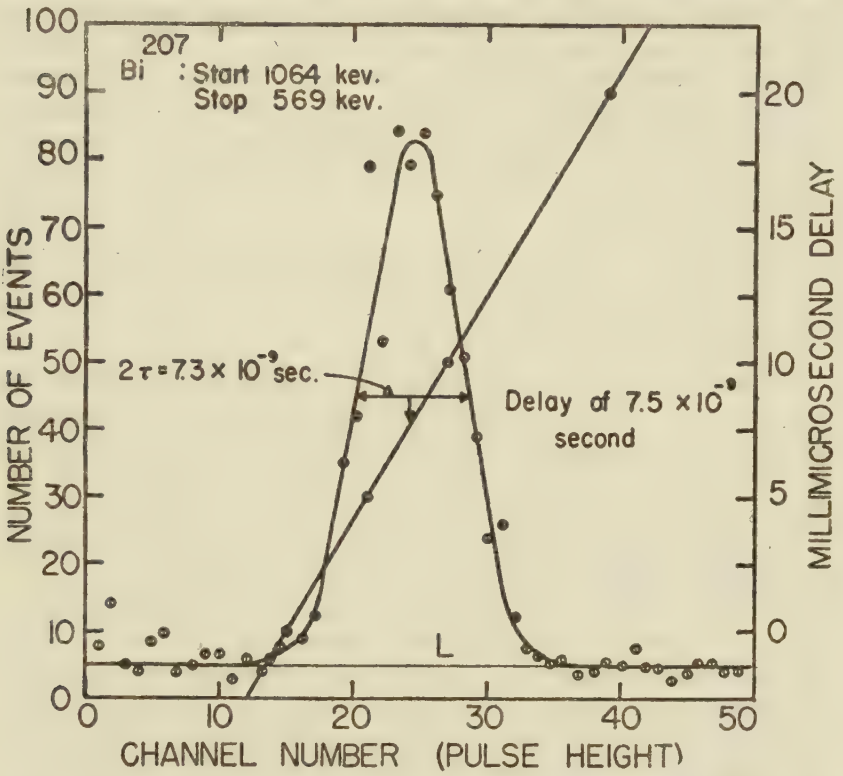


FIG. 12. THC coincidence spectrum for the 1064→569-Kev transition of Bi^{210}.

two conversion-electron pulses was evident from the shift of the peak position from channel 15 to channel 29.75, or a delay of 7.5 nsec based on the peak centroid shift. This was clearly in contradiction to the known properties of Bi^{207}. However, it must be remembered that the two electrons were traveling at different velocities. From fundamental laws the velocities were 0.97c and 0.48c for the 976-kev- and 482-kev-electrons, respectively, where c is the velocity of light. Since each had

[37] Arkiv Fysik 10 (1956) 523.

to travel a distance of 100 cm the difference in time between the two conversion electrons if they were emitted from the nucleus simultaneously amounted to 6.4 nsecond. The difference between the central shift (delay), 7.5 nsec, and 6.4 nsec was within the experimental error. Therefore in all experiments with electrons of different energies, corrections due to the difference in transit time should be applied.

In Fig. 12 a line L was drawn at the average value of the events per channel corresponding to the chance coincidence or the coincidence background per channel. In this result the chance coincidence was five counts per channel or 6 counts per nanosecond delay. If we add all the events that make up the peak and subtract the number of chance coincidences in that same area we obtain the true coincidence rate. In this case it amounted to:

Sum of events from channel 14 to 38 inclusive (25 channels)	851
Total number of chance coincidences in 25 channels	125
True coincidences observed	726
True-to-chance ratio, 726/125	5.8

Immediately after obtaining the coincidence results of the 1064-kev → 569-kev transitions the stop side of the spectrometer current was increased to focus the conversion electrons of the 1064–kev transition. This should not be in coincidence, for both sides of the instrument were looking at the same transition. The results conclusively showed that they were not in coincidence. (Fig. 13)

Electron-electron coincidences in Hg^{203}.—Similar electron-electron coincidence measurements were tried for Hg^{203} whose 279-kev transmission was in coincidence with the beta spectrum. By feeding the start pulses produced by the beta section of the spectrum and stopping with the pulses from either the K- or L-conversion electrons of the 279-kev transition, a peak was observed in the pulse-height analyzer. Since the energies of the beta particles and the conversion electrons were not too different from each other, the peak's controid appeared at the zero delay channel. Previous investigators reported the lifetime of this state to be 2 nanosecond.[38]

Hence, this electron-electron coincidence spectrometer would be a very powerful tool in the future solution and disentangling of the now complicated and unresolved decay schemes.

[38] Engelder, T. C. Phys. Rev. 90 (1953) 259.

APPLICATION OF THE COINCIDENCE SPECTROMETER IN THE STUDY OF EUROPIUM-154

In the study of the decay of Eu^{154} made by Juliano and Stephens,[39] electron-electron coincidences were tried using this

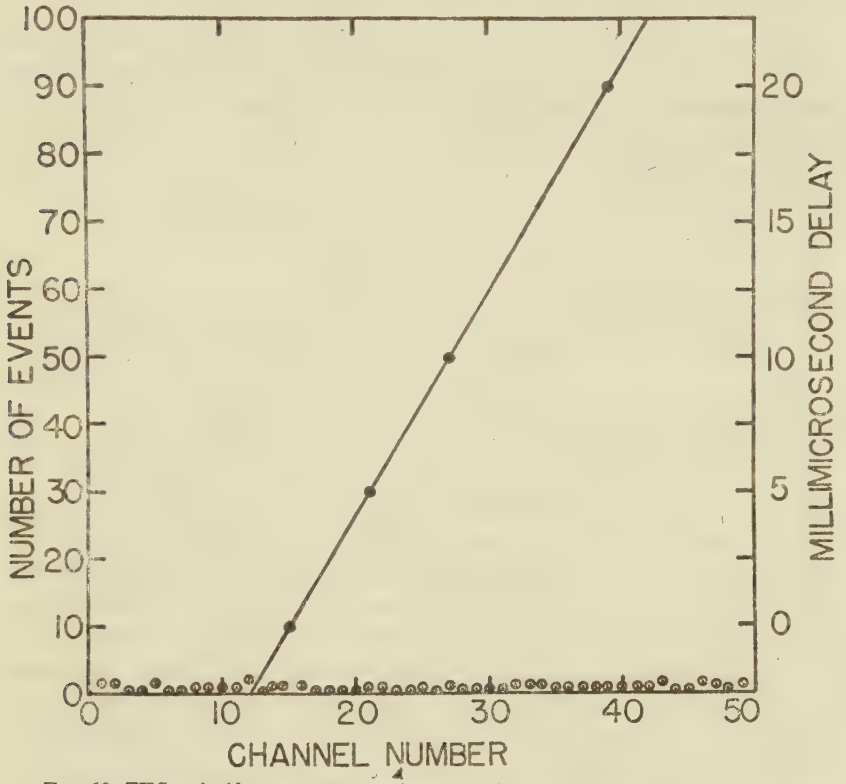


FIG. 13. THC coincidence spectrum of a typical noncoincidence transition pair.

coincidence spectrometer. With the 122.9-kev transition conversion electrons as the stop signal, the beta-spectrum pulses were fed into the start-pulse input. Enough events were collected for each case, and runs were made as long as two days when the counting rate was small. Since the results were collected in the form of a pulse-height distribution these were analyzed in the same way as Bi^{207} and Hg^{203}. When the original beta spectrum was normalized to the beta spectrum

[39] Phys. Rev. 108 (1957) 341.

in coincidence with the 122.9-kev transition by dividing it by an arbitrary constant, the fit was within experimental accuracy except near the 250-kev region and lower where the beta-spectrum chance contribution of Eu ^{155} was important.[40] This is so for the sample used had a lot of Eu ^{155} activity present.

There were only two transitions in Eu ^{154} where conversion-electron intensities were strong enough to be feasible for electron-electron measurements. They were the 122.9- and 247.9-kev transitions and the results obtained from them are presented below:

TABLE 2.—*Electron-electron coincidences of the 0.247- to 0.123-Mev transitions.*

Start pulse	Stop pulse	Counting time (min)	Chance coincidence	True coincidence	(True/chance) coincidence
K of 123 + B$^-$	*K* of 123 kev + B$^-$	400	150	493	3.3
K of 247 kev + B$^-$	*K* of 123 kev + B$^-$	1,194	140	1,273	9.1

Since the same stop pulses were used in both cases the only differences in the two measurements were the start pulses. The 122.9-kev plus beta-continuum pulses were more intense than the 247.9-kev plus beta pulses and hence their counting rate was higher, both for the true and chance coincidences. On the other hand, the true-to-chance coincidence ratio increased by 2.8 times in the second case in spite of the fewer events detected per unit time showing that the few conversion electrons of the 247.9-kev transition riding on top of the more numerous beta spectrum were in coincidence with the 122.9-kev transition. The results are in agreement with those obtained by Juliano and Stephens using gamma-electron and gamma-gamma coincidences.

CONCLUSION

The results obtained from this newly constructed nonferrous coincidence beta-ray spectrometer seem to indicate its possible future wide use in the complex field of nuclear spectroscopy.

Presently, Unik [41] is doing further work on this instrument with the hope of improving its transmission and his preliminary results are quite promising.

[40] Juliano, J. O. Philip. Jour. Sci. 88 (1959) 81–93.

[41] Unik, J. P. Private communication to J. O. Juliano (1958).

ILLUSTRATIONS

[Photographs reproduced by courtesy of the University of California Lawrence Radiation Laboratory.]

PLATE 1

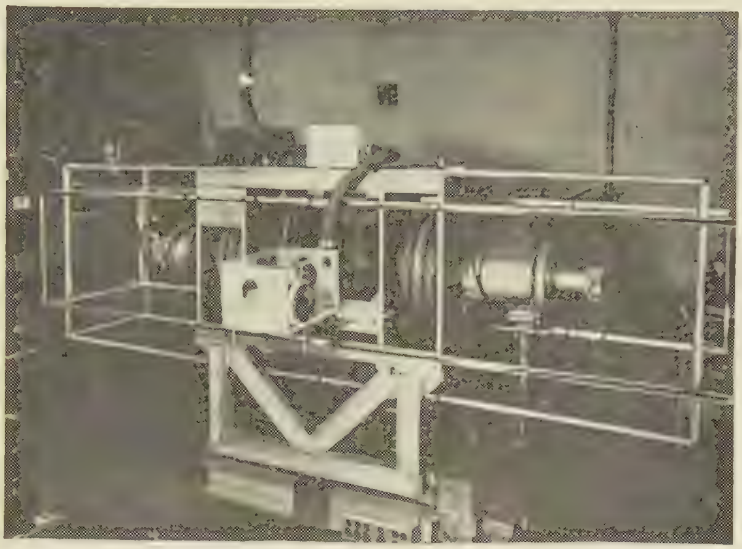
FIG. 1. Electron-electron coincidence spectrometer.
2. Control and counting panel for the electron-electron coincidence spectrometer.

PLATE 2

FIG. 1. Spectrometer baffle.
2. Cs^{137} conversion-electron picture at the ring-focusing position.

TEXT FIGURES

FIG. 1. Longitudinal section of the electron spectrometer.
2. Simplified wiring diagram of the main magnet coils.
3. Simplified wiring diagram of the trimmer coils.
4. Magnet-current block diagram.
5. Fast-slow coincidence-circuit block diagram.
6. Dimension of aluminum ring-focusing baffle based on Plate 2, fig. 2.
7. Effect of the magnetic field on the Cs^{137} K-conversion-electron line of the opposite spectrometer when no trimmer coils were used.
8. Effect of the magnetic field of the opposite spectrometer on the L-line of the 60-kev transition of Am^{241} with the proper trimmer coils.
9. Compensating effect of the trimmer coils on the opposite spectrometer using the beta spectrum of Cs^{137}.
10. Calibration curve of the spectrometer.
11. Calibration curve of the time-to-height converter (THC).
12. THC coincidence spectrum for the 1064-kev→569-kev transition of Bi^{207}.
13. THC coincidence spectrum of a typical noncoincident transition pair.



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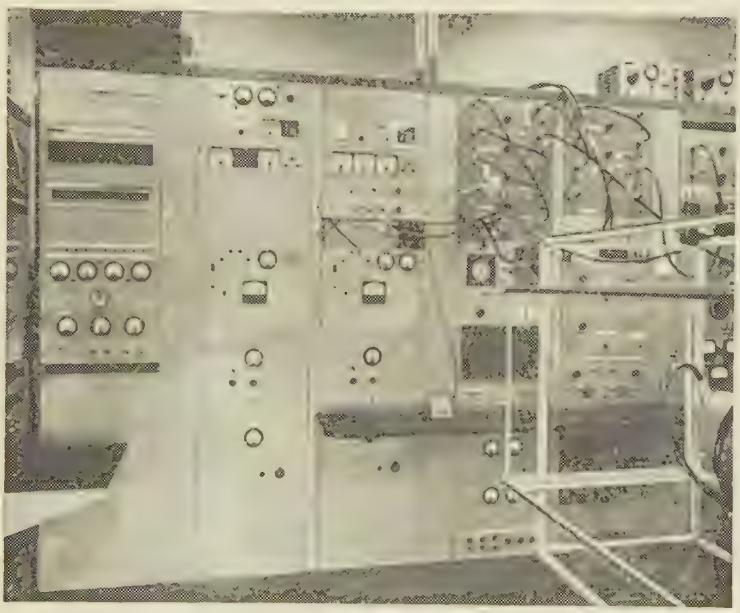

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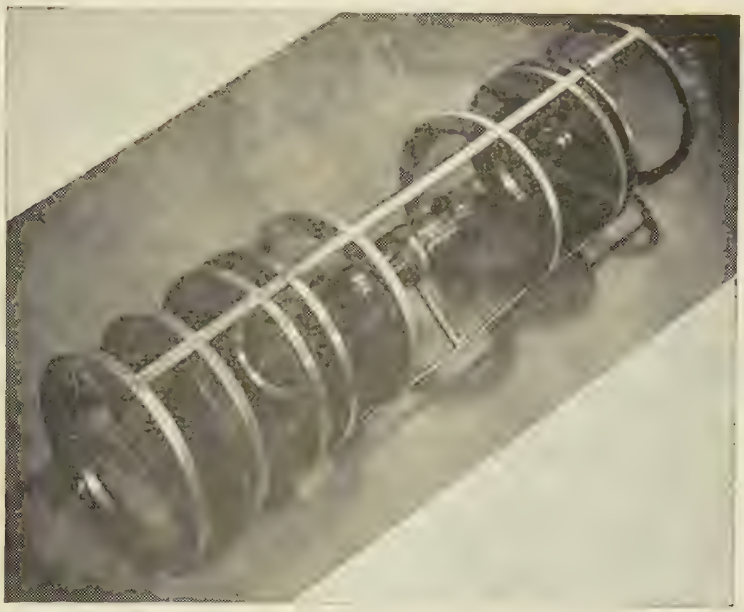
PLATE 1.



1

2

PLATE 2.

THE ATOMIC WEIGHTS OF IRON–52 AND MANGANESE–52m

By Jose O. Juliano
Philippine Atomic Energy Commission, Manila

ONE TEXT FIGURE

Closed-cycle and energy-balance calculations have been very useful in the prediction of properties of nuclides, both known and still unreported. In these approaches it is assumed that the energy and mass of the system are conserved through the well-known mass-energy relationship of Einstein. With these calculations it is possible to determine accurately the atomic masses of unstable nuclides which because of their very short half-lives make direct mass spectrographic determinations quite difficult. Once these masses are determined and tabulated they can be used in the study of nuclear energy surface thermodynamics and in other related theoretical studies of the structure of the nucleus where accurate masses of the nuclides both stable and unstable would be a necessity. With these principles in mind and with the recent data [1] on Mass–52 isobars, namely, the decay of Fe^{52}, it was decided to recalculate the masses of Fe^{52} and Mn^{52m}.

PROCEDURE, METHOD, AND DISCUSSION

The decay of the 8.2-hour Fe^{52} nuclide was studied by Juliano, et al.[1] using conventional beta-gamma and coincidence spectrometry. They reported the direct position and electron capture population of the 555-kev state of Mn^{52}. Combining the known nuclear data on the Mass-52 isobars [2] with these recent experimental results, a revised nuclear decay scheme for Fe^{52}, Mn^{52m}, and V^{52} is presented in Fig. 1. From the reported position and gamma-ray transition energies the Q values were

[1] Juliano, Kocher, Nainan, and Mitchell. Phys. Rev. 133 (1959) 602–608.
[2] Strominger, D., J. M. Hollander, and G. T. Seaborg. Rev. Modern Phys. 30 (1958) 585.

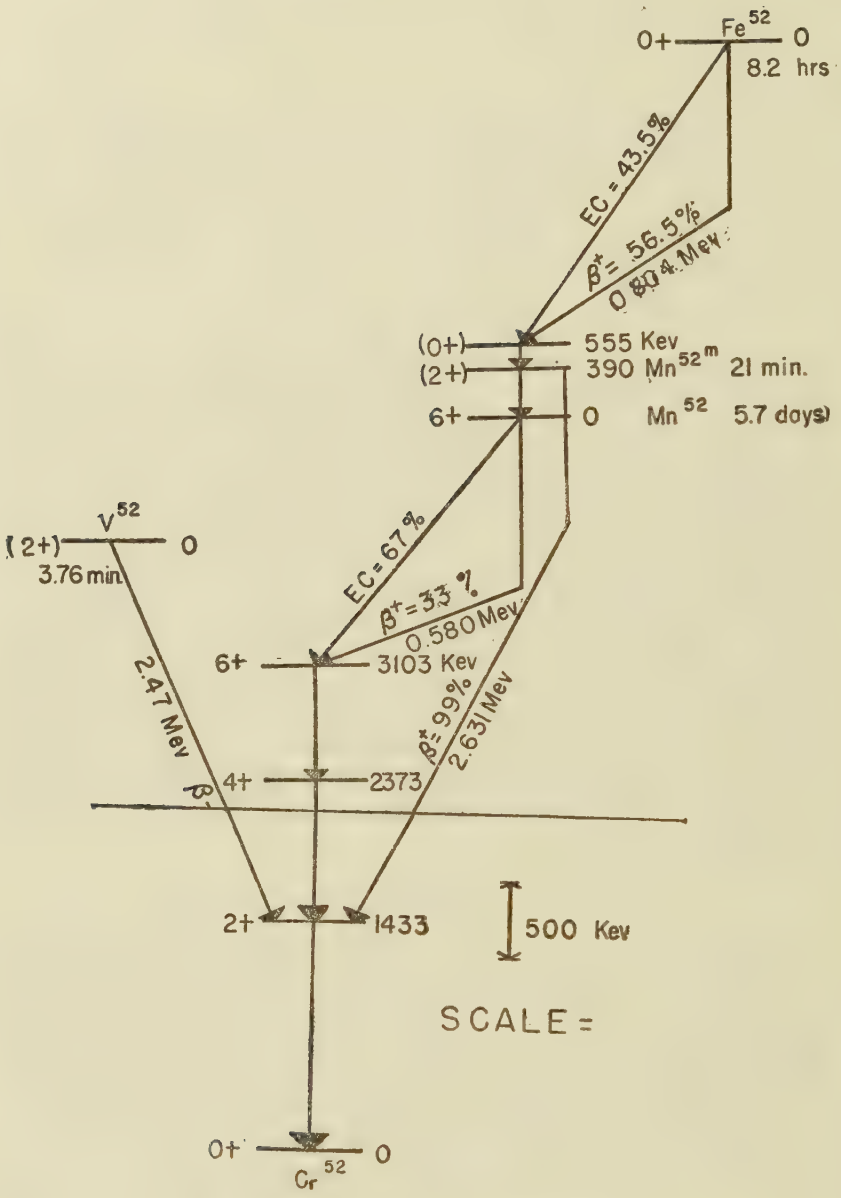


FIG. 1. Energy levels of the Mass-52 isobars.

TABLE 1.—*Mass-52 isobars.*

Nuclide	$t_{1/2}$	Reported atomic masses		Proposed masses
		Wapstra	Bainbridge	
		amu	*amu*	*amu*
Fe^{52}	8.2 hrs.	51.96421	----------	51.96453
Mn^{52m}	21.0 min.	----------	----------	51.96239
Mn^{52}	5.7 days	51.96207	51.96202	51.96202
V^{52}	3.8 min.	51.961184	51.9607	51.9611
Cr^{52}	stable	51.95699	51.95693	(51.95693)***

*** Based on Bainbridge's data.

calculated using the atomic constants of Cohen, et al.[3] and Bearden and Thomsen.[4] The results are given in Table 1.

As a basis for calculation, the masses in this report were determined using the mass of Cr^{52}, 51.95693, as reported by Bainbridge. The calculated mass of Mn^{52} compares favorably with the data of both Wapstra [5] and Bainbridge.[6] However, for V^{52} the present result differs from that of Bainbridge, the probable reason being the reported decay scheme of V^{52} at that time was in error and not fully understood. With the more recent values from improved beta-ray spectroscopy techniques, Wapstra's data and this paper agree within experimental error on the mass of V^{52}. As for the mass of Mn^{52m}, no previous data on this isomer has been published and hence no comparison can be stated. However, it is felt that the given mass for Mn^{52m} of 51.96239 amu is quite accurate. It is now interesting to compare the masses reported by Wapstra for Fe^{52} with that of this report. Wapstra's value is smaller than that presently proposed for Fe^{52} because the decay of $Fe^{52} \xrightarrow{B+/EC} Mn^{52}$ was not yet fully known when his results were published and it was just recently that a new 165-kev electromagnetic transition was reported, thus increasing the Q value of the position decay of Fe^{52} and also its calculated mass. Furthermore, Wapstra's value was based on semi-theoretical assumptions, whereas the present value is an experimental result.

[3] Cohen, DuMond, Layton, and Rollett. Rev. Modern Phys. 27 (1955) 363.

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THE OXALIC ACID CONTENT OF SOME PHILIPPINE FOOD PLANTS

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Certain chemical substances present in food plants, as it is generally known, interfere in the utilization of calcium in the diet. Oxalates found in foods when taken into the body, for instance, combine not only with the dietary calcium but also with magnesium to form insoluble oxalates which are rendered unavailable for body use and are excreted in the feces. As is also generally recognized, calcium deficiency in the human diet is the cause of certain diseases unless such deficiency is supplemented in liberal amounts with other sources of calcium like milk, butter, and eggs. But because these latter foods are not within the easy reach of the poor people, vegetables are to them the only main source of dietary calcium.

The role played by the presence of oxalates in foods has been the subject of previous investigations. Fairbanks and Mitchell(3) state that the addition of sodium oxalates to diets of skimmed milk powder depressed the calcium utilization by 24 to 38 per cent. Studies conducted by Mitchell and Hamilton(7) on the effect of cocoa upon the retention of dietary calcium by growing rats show that two medium-priced breakfast cocoas containing 22 to 24 per cent fat depressed calcium assimilation in growing rats in proportion to their contents of oxalic acid. The cocoas themselves contained enough calcium to combine with 54 per cent of their contents of oxalic acid.

Studies of Kohman(5) show that oxalates, expressed as anhydrous oxalic acid, occur to the extent of about 10 per cent on a dry basis in spinach, beet tops, parsley, and rhubarb. Traces were found in nearly all fruits and vegetables studied by him. A diet of meat, peas, carrots, and sweet potatoes, to which spinach was added to the extent of about 8 per cent to supply 60 per cent of the calcium, when given to rats between the ages of 21 and 90 days, resulted in a high death rate in the animals. The studies indicate that spinach not only did not supply available calcium to rats in spite of its high calcium content, but also rendered unavailable a large part of the calcium from the rest of the diet. Reproduction in the animals was rendered impossible, the bones were low in calcium, and their tooth structure was disorganized.

At the University of Hawaii Agricultural Experimental Station(6) studies also show that vegetables like amaranth, parsley, spinach, Malabar nightshade, Hawaiian taro, taro leaves, and sweet-potato tops contain sufficient or more than sufficient oxalic acid to combine with calcium present.

Bendaña-Brown and Lim (2) in their investigation of the calcium and oxalic acid content of some Philippine food plants report that several of the calcium-rich vegetables, such as pepper leaves, *alugbati, olasiman, kolitis,* and *talinum,* contain oxalic acid in great excess of their calcium content thus rendering unavailable to the body not only all of the calcium in the vegetables but also calcium from other sources in the diet.

The purposes in undertaking the present study were to determine the oxalate content of some local food plants and to utilize the data obtained therefrom as a basis for avoiding the use of those with high percentage of oxalates.

EXPERIMENTAL PROCEDURE AND RESULTS

The specimens for this study were obtained from local plants purchased in the markets of Manila.

The vegetable samples were thoroughly washed so as to remove all foreign matter and were allowed to drain and to dry in air until the surface contained no excess water. The edible portion of the vegetable samples was separated from the nonedible. The moisture content of a representative sample of the fresh, edible portion of each specimen was determined following the method recommended by the Association of Official Agricultural Chemists.(1) The remainder was dried in an infrared dryer at about 80°C. The dried samples were ground to a coarse powder in a Wiley mill and stored in well-stoppered bottles. The oxalic acid contents 71 Philippine food plants were determined with the use of the modified Arbenz method described by Hoover and Karunairatnam.(4)

The results of the study show that some local food plants (Table 1) have relatively high oxalate content. In 37 leafy vegetables, oxalates, expressed as anhydrous oxalic acid, occurred to the extent of 1 to 2 per cent in each fresh sample of *kolitis, malungay, alugbati, pasau-na-haba, sile* leaves, *talinum, bunga-bunga,* and *olasiman.* The rest of the vegetables analyzed contained smaller amounts. In the dry samples, the oxalate content was more than 16 per cent in *talinum,* 13 per cent in *olasiman,* 11 per cent in *alugbati,* and 10 per cent in

TABLE 1.—*Oxalic acid content of some Philippine food plants.*

Local and scientific name	Part analyzed	Moisture content	Oxalic acid content	
			Fresh samples	Moisture free samples
		Per cent	*Per cent*	*Per cent*
Abitsuelas (*Phaseolus vulgaris* Linn.)	Pods	91.6	0.012	0.14
Alibangbang (*Bauhinia malabarica* Roxb.)	Leaves and tops	75.91	0.2	0.831
Alugbati (*Basella rubra* Linn.)	Leaves and tops	91.4	1.0	11.3
Ampalaya (*Momordica charantia* Linn.)	Leaves	76.72	0.53	1.69
Do	Fruit	91.16	0.15	1.7
Bago (*Gnetum gnemon* Linn.)	Leaves and tops	76.6	0.337	1.44
Balatong [*Glycine max* (Linn.) Merr.]	Seeds	7.81	0.455	0.494
Bauang (*Allium sativum* Linn.)	Leaves	89.75	0.303	2.95
Do	Bulbs	63.96	0.215	0.597
Bunga-bunga [*Alternanthera sessilis* (Linn.) R. Br.]	Young leaves	82.65	1.4	8.08
Cabbage or repollo (*Brassica oleracea* Linn. var. *capitata* Linn.)	Leaves	93.15	0.026	0.381
Celery (*Apium. graveolens* Linn.)	Petioles	89.64	0.036	0.347
Gabi [*Colocasia esculentum* (Linn.) Schott and Endl.]	Leaves	76.5	0.77	3.77
Do	Tuber	51.8	0.145	0.302
Himbabau *alleanthus luzonicus* (Blco.) F. Vill.	Leaves	74.38	0.384	1.5
Kalabasa (*Cucurbita maxima* Duchesne)	Leaves and tops	83.47	0.292	1.77
Do	Fruit	89.13	0.034	0.314
Kalamismis [*Psophocarpus tetragonolobus* (Linn.) DC]	Fruit	92.73	0.037	0.509
Kamatis (*Lycopersicum esculentum* Mill.)	Fruit	93.27	0.017	0.255
Kamias (*Averrhoa bilimbi* Linn.)	Fruit	94.97	1.06	21.21
Kamote [*Ipomoea batatas* (Linn.) Poir.]	Leaves and tops	85.36	0.83	5.67
Do	Root	68.0	0.054	0.168
Kamoteng-kahoi (*Manihot esculenta* Crantz.)	Young leaves	69.21	0.517	1.67
Kangkong (*Ipomoea aquatica* Forsk.)	Leaves and tops	86.23	0.94	6.75
Katuray [*Sesbania grandiflora* (Linn.) Pers.]	Flowers	86.48	0.024	0.181
Kauayan tinik (*Bambusa spinosa* Roxb.)	Shoot (Labong)	91.69	0.029	0.352
Kinchai, Tsina (*Apium graveolens* Linn.)	Leaves and petioles	85.71	0.406	2.84
Koles (*Brassica oleracea* Linn. var. *acephala* DC.)	Leaves	87.76	0.080	0.653
Kolitis (*Amaranthus viridis* Linn.)	Leaves	80.08	2.23	10.08
Kuchai (*Allium tuberosum* Roxb.)	Leaves	90.64	0.069	0.745
Labanos (*Raphanus sativus* Linn.)	Root	94.31	0.105	1.77
Leek (*Allium porrum* Linn.)	Leaves and bulbs	88.69	0.128	1.13
Letsugas (*Lactuca sativa* Linn.)	Leaves	93.58	0.22	2.19
Luya (*Zingiber officinale* Rosc.)	Rhizome	94.43	0.191	3.43
Malunggay (*Moringa oleifera* Lam.)	Leaves	70.65	1.33	4.54
Mangga (*Mangifera indica* Linn.)	Green fruit	76.08	1.5	6.27
Mongo (*Phaseolus aureus* Roxb.)	Seed sprouts	94.66	0.019	0.020
Mustasa (*Brassica integrifolia* O. E. Schulz.)	Leaves	92.95	0.12	2.04
Okra (*Hibiscus esculentus* Linn.)	Fruit	92.54	0.094	1.26
Olasiman (*Portulaca oleracea* Linn.)	Leaves	87.1	1.17	13.59
Paayap [*Vigna sinensis* (Linn.) Savi.]	Fruit	89.44	0.067	0.654
Pakó [*Athyrium esculentum* (Retz.) Copel.]	Leaves	86.82	0.286	2.68
Papaya (*Carica papaya* Linn.)	Green fruit	93.8	0.076	1.22
Pasau-na-haba (*Corchorus olitorius* Linn.)	Leaves	77.25	1.34	5.92
Patatas (*Solanum tuberosum* Linn.)	Tuber	86.1	0.069	0.496
Patola [*Luffa cylindrica* (Linn.) M. Roem.]	Fruit	95.49	0.022	0.485
Petsai (*Brassica chinensis* Linn.)	Leaves	92.11	0.15	1.84
Petsai, Tsina (*Brassica cernua* (Thunb.) For. and Hensl.]	Leaves	94.6	0.439	3.13
Pepino (*Cucumis sativus* Linn.)	Fruit	96.46	0.021	0.585
Remolatsa (*Beta vulgaris* Linn.)	Root	88.72	0.093	0.824
Saging [*Musa sapientum* Linn. var. *compressa* (Blco.) Teod.]	Inflorescence	91.86	0.472	5.77
Sampalok (*Tamarindus indica* Linn.)	Young leaves and flowers	73.15	0.8	2.98
Do	Fruit	69.93	5.82	19.35
Sarsalida [*Glinus oppositifolius* (Linn.) DC]	Leaves	91.07	0.906	10.15
Sayote (*Sechium edule* Sw.)	Fruit	94.2	0.034	0.583
Sibuyas (*Allium cepa* Linn.)	Leaves	89.67	0.042	0.404
Do	Bulbs	84.66	0.097	0.632
Sile (*Capsicum frutescens* Linn.)	Leaves	77.78	1.79	7.61
Sileng-bilog (*Capsicum annuum* Linn. var. *grossum* Sendt.)	Fruit	89.14	0.175	1.61

TABLE 1. *Oxalic acid content of some Philippine food plants*—Cont.

Local and scientific name	Part analyzed	Moisture content	Oxalic acid content	
			Fresh samples	Moisture free samples
		Per cent	*Per cent*	*Per cent*
Sinkamas [*Pachyrrhizus erosus* (Linn.) Urb.]	Root	89.61	0.058	0.558
Sitau (*Vigna sesquipedalis* Fruw.)	Leaves	83.97	0.879	5.48
Do	Young pod	86.62	0.035	0.261
Sitsaro (*Pisum sativum* Linn.)	Young pod	87.3	0.156	1.23
Talinum (*Talinum triangulare* Willd.)	Leaves	93.06	1.14	16.53
Talong (*Solanum melongena* Linn.)	Fruit	91.94	0.027	0.336
Tañgo (*Chrysanthemum coronarium* Linn.)	Leaves	92.62	0.152	2.07
Uan-suy (*Coriandrum sativum* Linn.)	Leaves and tops	87.01	0.372	2.86
Ubi (*Dioscorea alata* Linn.)	Root	73.10	0.153	0.569
(Upo [*Layenaria leucantha* (Duch.) Rusby]	fruit	95.70	0.022	0.512
Watercress (*Roripa nasturtium-aquaticum* Hayek.)	Leaves	92.4	0.52	0.408

kolitis and *sarsalida*. In 34 non-leafy vegetables, oxalates, expressed as anhydrous oxalic acid, was found present in *kamias*, green mangoes and green sampalok to the extent of 1 to 5 per cent in the fresh sample. In all other non-leafy vegetables, the content was in much smaller amounts.

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THE PHONEMES OF TAGABILI

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INTRODUCTION

0.1. Synopsis.

We consider that the phonemes of Tagabili include seven vowels /a/, /e/, /é/, /i/, /o/, /u/ /ú/; fiften consonants, /b/, /k/, /d/, /f/, /g/, /h/, /l/, /m/, /n/, /ng/, /s/, /t/, /w/, /y/, /q/; accent (rarely contrastive); and at least five contrastive intonation patterns.

Unsuffixed words have CVC in the final syllable, and CV or CVC in preceding syllables. Within this pattern the only restrictions on consonants are in CC clusters, and vowels are restricted by the vowels of adjacent syllables.

0.2. Background.

Tagabili is a dialect spoken by an estimated 20,000 living in southern Cotabato, Mindanao, Philippines, in an area including the Alah Valley, Lake Sebu, and southwest to the coast. They are almost entirely monolingual, though a few, through contacts with the settlers, have learned some Hiligaynon (Ilongo). Now that schools have been opened in a few centers, some of the younger generation are learning a little English.

Four mutually intelligible dialects have been observed: (*a*) Maitum area near Kiamba, on the west coast of Cotabato; (*b*) the area around Lake Sebu; (*c*) the area around the headwaters of the Alah River; and (*d*) Lamian and Sinolon areas in the Alah Valley, and in the mountains to the east of the valley (each with slight differences).

The name by which the people refer to themselves is /tebolih/. Tagabilis of the Sinolon area refer to the Tagabilis living west of Lake Sebu as /qúbúq/. Settlers in the area refer to all Tagabilis as 'Bilaans'.

The field work for this paper was done during the years 1953–55 in the barrio of Sinolon under the auspices of the Summer Institute of Linguistics. The main informants were

Alfredo Piang, age 20 years, and Mariano Antay, age 16 years, both trilinguals, speaking Ilongo and some English in addition to their own language.

VOWELS

There are seven vowel phonemes. These are /a/, /e/, /é/, /i/, /o/, /u/ and /ú/. All vowels occur in both open and closed syllables.

1.1. Restrictions of occurrence.

Certain restrictions of occurrence have been noted for the vowels of two-syllable words. (The vast majority of word-bases are disyllabic).

/ú/ has not been observed to occur in the first syllable unless the second also contains /ú/.
/é/ has not been observed to occur in the first syllable unless the second also contains /é/.
/é/ has not been observed to occur in the second syllable if the first contains /i/, /a/, /ú/, or /o/.
/a/ and /o/ rarely occur in the first syllable if the second contains /e/ or /ú/.
/a/ and /o/ have not been observed to occur together in one word base.

As many Philippine languages have only three, four, or five phonemic vowels, every effort has been made in the following pages to present the evidence for the contrast between the seven Tagabili vowel phonemes. For those contrasts which are not highlighted, the evidence is included among the lists of phoneme examples. Comparative evidence concerning the historic development of these seven vowels is discussed in the appendix.

1.2. Description of vowels.

/i/.[1] /nih *here;* /biq/ *small girl;* /sit/ *maya /bird*) ; /qidip/ *aunt;* /sanih/ *scorched food;* /sigih/ *a brush;* /ketih/ *dried up;* /suliq/ *sucker, shoot;* /kitay/ *bridge;* /libun/ *boy's sister;* /libol/ *rice soup;* /sungit/ *to eat with fingers.*

/é/. A close allophone occurs preceding /y/; the open allophone occurs elsewhere. /kéh/ *young hornbill;* /féq/ *sibling-in-law of opposite sex;* /yéq/ *mother;* /muléh/ *go over;* /tebéh/ *needle;* /teféq/ *slap, spank;* /qulék/ *return;* /méylés/ *envious;* /meféyúw/ *rice stem whistle;* /yéy/ *an exclamation.*

[1] See the appendix for technical description of phonemes.

/a/. The phoneme /a/ is never found in the first syllable of a three-syllable word. /nah/ *exclamation of surprise;* /fan/ *bait*; /sanah/ *eat one item;* /matuq/ *win;* /budas/ *faded;* /kayang/ *hold aloft;* /qatal/ *lipstick;* /sawiq/ *pigeon-toed;* /mimah/ *long time.*

/e/. This vowel is short in non-final unaccented syllables, and normal length in final syllables and accented syllables. /neh/ *and;* /beq/ *a prepositional form*; /dek/ *pestle;* /qehek/ *planting stick;* /lebol/ *murky, riled;* /sunget/ *jealous;* /melel/ *flow;* /helafus/ *morning.*

/o/, /koh/ *hornbill;* /qulok/ *defective speech;* /doquh/ *I, mine;* /mokoh/ *chew suqarcane;* /lobun/ *cloud;* /heltoq/ *jump over;* /senolok/ *to light;* /tenobong/ *young, immature vegetable.*

/ú/. This vowel is unrounded in the Maitum dialect. /yúq/ *daughter-in-law;* /ketúh/ *torn;* /tebúh/ *dilapidated;* /tútúl/ *well-known;* /sulúq/ *pig trap;* /mimún/ to *obey;* /tenúbúng/ *to help;* /senúlúk/ *to ask.*

/u/. /fuq/ *great-grandfather*; /fun/ *owner;* /sut/ *born, arrive;* /qudiq/ *small;* /siguh/ *elbow;* /muluh/ *crawl;* /mutuq/ *protrusion, peak;* /tefuq/ *frighten away rain;* /budus/ *cradle-cap;* /qatul/ *idea;* /suwiq/ *wrong;* /mimuh/ *to lick up food scraps.* In about 20 per cent of words in which /u/ occurs in one syllable and /a/ or /o/ in the other syllable, the /u/ freely alternates with /u/; /u/ is usually the pronunciation preferred. In the Maitum dialect there is no fluctuation, all such words being pronounced with /u/. /qohuh/ or /qohúh/ *dog;* /qonuk/ *or* /qonúk/ *chicken;* /tahuh/ or /tahúh/ *true;* /qukol/ or /qúkol/ *short;* /kudaq/ or /kúdaq/ *horse.*

1.3. Minimal pairs to contrast vowels.[2]

/é/versus /i/.

béq	*don't*	biq	*small girl (address)*
kéq	*fecal matter*	kiq	*vagina*
tuwél	*pour out*	tuwil	*a prying tool*
qéhéh	*excuse me*	qihih	*I told you so*
bél	*talkative, happy*	bil	*tail of pig*

/a/ versus /e/.

qah	*exclamation*	qeh	*yes*
mah	*fetch*	meh	*we, our*
wak	*crow*	wek	*hair*

[2] Slant brackets have been omitted from phonemic material in Sections 1.3, 4.2, 8, and 9.3.

bang	*mark*	beng	*wall*
balih	*spoiled*	belih	*to buy*
malah	*pepper*	melah	*sow seed in hole*
matem	*respect*	metem	*burn up*
mafas	*pull away*	mefas	*cut grass*
mesaf	*peel, as sugarcane*	mesef	*to nurse (suckle)*
tulad	*picture*	tuled	*illness*
sabat	*game (cat's cradle)*	sebat	*spear*
sengal	*song*	sengel	*dazzled*
sebalaq	*two carrying*	sebelaq	*across from*

/a/ versus /o/.

maq	*father*	moq	*to work*
bang	*mark*	bong	*big*
menaq	*shrink*	menoq	*dissolve*
lembang	*big*	lembong	*variety of banana*
kafih	*three-fourths full*	kofih	*hawk*
talak	*middle of*	tolok	*teach*
lamih	*harvested field*	lomih	*new*

/ú/ versus /u/.

kúm	*you, yours*	kum	*us, our*
kúl	*to arrive*	kul	*they, their*
súk	*harelip*	suk	*knife*
helús	*to proceed*	helus	*to give permission*
qilúh	*husk of rice*	qiluh	*orphan*
lungún	*weaving shuttle*	lungun	*coffin*
lulún	*a load*	lulun	*to roll up*
melúy	*to run*	meluy	*to roll off*
munúh	*to sweep*	munuh	*unsatisfactory*
sulúd	*misaligned tooth*	sulud	*comb*
tedúk	*finger*	teduk	*to ache*
tukúq	*peak, tip*	tukuq	*hair bun*

/ú/ versus /o/.

kúh	*to remove*	koh	*hornbill*
kúl	*to arrive*	kol	*owl*
súk	*harelip*	sok	*if*
túq	*almost*	toq	*son-in-law (address)*
helús	*to proceed*	helos	*type of mushroom*
meluh	*smooth*	meloh	*frighten away*
lewúk	*wave of sea*	lewok	*tears*
sedúq	*pig*	sedoq	*to command another*

/o/ versus /u/.

bot	*throw away*	but	*beginning*
doh	*I, mine*	duh	*that*
soq	*snail*	suq	*to put*
sok	*if*	suk	*knife*
logih	*male*	lugih	*to lose out*
qohuh	*dog*	quhuh	*deer*

qoquh	*I*	ququh	*you*
soluh	*facing*	suluh	*fill container by submerging it*
bolok	*swollen*	boluk	*to lift up*
helos	*type of mushroom*	helus	*to give permission*
lemnos	*strong wind*	lemnus	*die of starvation*
lefoq	*coconut*	lefuq	*a joint*
mugod	*tumble down*	mugud	*bathe with a stone*
tebol	*padded drumstick*	tebul	*continuous trickle*

/a/ versus /é/.

kuwang	*one's back*	kuwéng	*pour*
mukat	*open one's eyes*	mukét	*remove husk*
qulat	*vein*	qulét	*lines in palms of hands*

/a/ versus /ú/.

laq	*no, not*	lúq	*young girl (address)*
bilaq	*friend*	bilúq	*broken rice kernel*
munah	*rotten*	munúh	*sweep*

/e/ versus /é/.

beq	*to*	béq	*don't*
weq	*friend*	wéq	*girl's sibling-in-law (address)*
keleb	*gabi (vegetable)*	keléb	*gravel-like stones*
kuleng	*pot*	kuléng	*cricket*
sefeng	*lid*	seféng	*twins*

/e/ versus /o/.

beng	*wall*	bong	*big*
del	*recompense for insult*	dol	*handle of pot*
des	*illness*	dos	*spouse of sibling-in-law*
ketih	*dried up*	kotih	*edible plant*
sedoq	*order, command*	sodoq	*two riding one horse*
gesel	*repent*	gesol	*thorn*
henek	*small pieces*	henok	*favoring small child*
mebel	*look for*	mebol	*loosen of itself*
nungel	*foolish*	nungol	*hear*
seket	*plant, fragrant*	sekot	*snatch up*
sigel	*arm*	sigol	*crooked*
tebel	*leave*	tebol	*padded drumstick*

/e/ versus /ú/.

kem	*plural article*	kum	*you, your*
dek	*pestle*	dúk	*command*
nem	*six*	núm	*taste*
tek	*only*	túk	*type of bolo*
tuged	*walk with cane*	tugúd	*interpret*

/e/ versus /u/.

kem	*plural article*	kum	*we, our*
ken	*food*	kun	*3rd person singular*
ket	*each*	kut	*they, their*
hesek	*servant, slave*	husek	*enter*
meteb	*chew unhusked rice*	muteb	*to mouth words*
melem	*water-logged*	melum	*damp, moldy odor*
melef	*die*	meluf	*burn oneself*

CONSONANTS

There are 15 consonant phonemes. These are: /b/, /k/, /d/, /f/, /g/, /h/, /l/, /m/, /n/, /ng/, /s/, /t/, /w/, /y/ and /q/. All occur in syllable initial and final positions.

2.1. Stops.

All stops are unreleased before a pause.

/b/. /beq/ *don't;* /buh/ *fishing net;* /qabuq/ *fat;* /gebaq/ *destroyed;* /qibah/ *mistake;* /neb/ *silent;* /tilob/ *pretty;* /neben/ *to wrap in blanket.*

/t/. /kut/*we, our;* /tuh/ *there;* /telem/ *sharp;* /matak/ *unripe;* /mesut/ *to be born;* /tétéq/ *filthy;* /but/ *beginning.*

/d/. The usual pronunciation is /d/. Flapped /r/ is found infrequently in intervocalic position and has been noted only in the speech of those who have had contact with another dialect, such as Ilocano or Ilongo. /kudaq/ and occasionally /kuraq/ *horse;* /duh/ *that;* /delem/ *foot of hill, mountain;* /qudiq/ and occasionally /quriq/ *little;* /mesud/ *to remodel;* /bud/ *again.*

/k/. /koyuh/ *tree;* /makan/ *large mat;* /sukeq/ *hair parting;* /hanak/ *arrow;* /hulúk/ *eyebrow;* /metek/ *leech;* /tefék/ *expel air through lips.*

/g/. /goyuh/ *banana stalk;* /giqus/ *exactly right;* /sugéq/ *contest;* /lagan/ *section of a loom;* /sugal/ *card game;* /meteg/ *raise to an upright position.*

/q/. Glottal stop contrasts with /h/ in word-final position.

/balaq/ *to answer*	/balah/ *embers*
/qibaq/ *tart citrus fruit*	/qibah/ *mistake*
/mesúq/ *split lengthwise*	/mesúh/ *husked rice*

Intervocalic glottal has been observed to occur with only six combinations of unlike vowels: /qaqut/ *ladder;* /kewaqih/ *spider;* /luqos/ *rattan*; /qoquh/ *I;* /giqus/ *exact;* /tiqol/ *bone.*

About 70 per cent of intervocalic glottals occur between like vowels: /maqan/ *lightweight;* /teniqih/ *little finger;* /senéqél/ *jerk (winnowing);* /senúqúl/ *comb of fowl;* /leqef/ *temporarily deafened;* /lembuqut/ *cloudy;* /boqok/ *foolish.*

2.2. Fricatives.

/s/. A slightly fronted variant of /s/ occurs word initially preceding /iy/. /siyúm/ *nine;* /siyamih/ *type of ant;* /soq/ *snail;* /suq/ *put;* /sol/ *hole;* /salah/ *nest;* /hesek/ *slave, servant;* /melus/ *loosen;* /mudos/ *polish;* /salaq/ *mistake.*

/f/. /féq/ *sibling-in-law, opposite sex;* /fuq/ *great grandfather;* /fol/ *storehouse;* /kifuh/ *night;* /gefaq/ *trouble;* /sufúq/ *large, thorny bamboo;* /meluf/ *burn oneself;* /mudof/ *blink;* /falaq/ *shovel.*

/h/. /hoq/ *an exclamation;* /hol/ *an intensifier;* /kihuh/ *either one;* /halah/ *shelf above the fire;* /hehek/ *post.*

Word final /h/ is lost in utterance medial position, but is retained before pause and optionally before suffixes beginning with vowels. /duh/ *it;* /nuq se duh ne/ *Where is it now?;* /nih duh/ *Here it is;* /duhen/ *That's it.*

Word final /h/ only occurs on words with final accent. /h/ never occurs finally on unaccented suffixes or particles. (Sect. 3.1.)

In the Maitum dialect word final /h/ contrasts with word final vowel. However in the dialect described in this paper, word final vowel does not occur phonemically.

2.3. Liquids.

/m/. /muh/ *use, purpose;* /maq/ *father;* /miluh/ *to poison;* /namak/ *variety of banana;* /qamuq/ *dew;* /núm/ *taste;* /qutúm/ *descriptive music.*

/n/. /nem/ *six;* /nanak/ *core of boil;* /munuh/ *unsatisfactory;* /hatan/ *wait;* /múyún/ almost.

/ng/. /ngem/ *You see!;* /ngaq/ *child;* /munguh/ *bear fruit;* /mingaq/ *admirable;* /kebeng/ *link fingers;* /múyúng/ *to fly.*

In Tagabili the phoneme /ng/ contrasts with the phoneme clusters /n.g/ and /ngg/. /sengalem/ *your song;* /sen.galak/ *to lead;* /senggeled/ *squabble;* /hengeden/ *It's known as . . .;* /hen.gulam/ *careful;* /henggasam/ *salad of raw vegetables.*

/l/. /lem/ *inside;* /léwés/ *rainbow;* /muluh/ *crawl, as a snake;* /hilol/ *around;* /kebel/ *smoke;* /múyúl/ *slip down.*

SEMIVOWELS

In Tagabili the high close front unrounded vocoid and the high close back rounded vocoid have been phonemically interpreted as either vowels /i/ and /u/, or as consonants /y/ and /w/, or as vowel plus consonant /iy/ or /yi/ and /uw/ or /wu/. In any particular word the interpretation adopted depends upon:

(*a*) the best attested CV-pattern of words in Tagabili,[8]
(*b*) the immediate environment of the high vocoid (or cluster of high vocoids) within the given word,
(*c*) the phonetic nature of the high vocoid (or cluster of high vocoids).

3.1. CV—Patterns.

In Tagabili, unsuffixed words are composed of from one to four phonemic syllables. Phonemic syllables of two patterns occur: CV and CVC. The final syllable is always CVC.

CVC /mah/ *to fetch;* CV.CVC /dékah/ *might;* CV.CV.CVC /seléhéh/ *sprain;* CV.CV.CV.CVC /mebeliluh/ *rickety;* CVC /ton/ *see;* CVC.CVC /bentéq/ *cataract;* CVC.CV.CVC /semgalak/ *to lead;* CV.CVC.CVC /mefangkul/ *end over end;* CVC. CV.CV.CVC /semkeleyek/ *quarreling.*

An additional syllable pattern, CV, occurs on some word final unaccented syllables. The only cases of this are the three pronoun suffixes /-e/, /-u/ *first person singular* and /-i/ *second person singular,* and the seven accent-less monosyllabic particles /ne/ *and,* /ne/ *now,* /ke/ *if,* /he/ *yet,* /de/ *interrogative,* /dé/ *response,* /se/ (*meaning not determined*).

Consonant clusters, CC, frequently occur following the first vowel of a word, as a result of infixation. Their occurrence in other positions is relatively infrequent. No more than one cluster has been observed in any single word; that is, no word has been observed to contain more than two syllables of the pattern CVC.

With these restrictions in mind, a CV formula for Tagabili words may be represented thus:

$[Cv(C^*)]^n$ CVC [V(C)] n= 1, 2, or 3 (i.e., the [CV(C*)] syllable may be repeated as many as 3 times in a word.) (C*) may appear only once in a word.

[8] See appendix for symbols C, V, S, ϕ,:.

3.2 Environments significant in interpretation.

From a consideration of the CV formula for the Tagabili word structure, it can be deduced that a high vocoid may be preceded by any one of four different types of immediate environments: ϕ, V, C, CC.[4] Also a high vocoid may be followed by any one of these four environments. Some 15 possible total environment combinations are thus significant in their effect on the interpretation of high vocoids.[5] Eleven of these possibilities have been observed to date, and are discussed below. High vocoids have not yet been observed in the environments ϕ—ϕ, CC—ϕ, ϕ—CC, and V—CC.

3.3. Tagabili interpretations.

(*a*) A single high vocoid that occurs between two obvious vowels or between an obvious vowel and silence is interpreted as a single consonant:[6]

VSV /beloyoh/ *to sag;* /kewag/ *up and down movement.*
VSϕ /kédéw/ *cry;* /belay/ *to give.*
ϕSV /wehoq/ *an exclamation;* /yakuh/ *large worm.*

(*b*) A single high vocoid that occurs between an obvious consonant and an obvious consonant cluster is interpreted as a vowel:

CSCC /kumbing/ *musical instrument;* /minggel/ *beautiful;* /kelintang/ *musical instrument;* /selungsud/ *a bolo.*
CCSC /kemantib/ *a rut;* /kelumbud/ *braided abaca cord;* /temgifit/ *place name;* /tenbungaw/ *shaven head.*

(*c*) A single high vocoid that occurs between two obvious consonants is interpreted as a single vowel if short, and as a consonant plus homorganic vowel if long and glided, and as a consonant between two homorganic vowels if extra and glided:

CSC /sigol/ *crooked;* /sudul/ *push;* /qigam/ *mat;* /qudél/ *word;* /mekih/ *scrape;* /henuh/ *turtle.*
CS:C /benwuh/ *country.*
CS: :C /luwuh/ *two.*

[4] C may be ϕC or VC preceding a high vocoid, and Cϕ or CV following a high vocoid.

[5] 4 × 4 equals 16 combinations. However the environment CC—CC does not occur in Tagabili words.

[6] For the term "obvious" we are indebted to J. D. O'Connor and J. L. M. Trim in "Vowel, Consonant, and Syllable—A Phonological Definition," Word 9 (1953) 103–122.

(*d*) A single high vocoid that occurs between an obvious vowel and an obvious consonant cluster, CC, is interpreted as a single consonant when it is nonsyllabic and as a consonant plus vowel (or vice versa) when the high vocoid is syllabic and long:

VSC /méylés/ *envious*
VS:C /towuh/ *child-in-law*
CSV /henyas/ *charm stone;* /helwah/ *to play;* /lemwút/ *to leave;* /legwét/ *sound of tearing.*
CS:V /mutiyaq/ *charm stone;* /biyoquh/ *muscle of elbow;* /lebuwon/ *clay water jar;* /buwak/ *upstream.*

(*e*) A single high vocoid that occurs between an obvious vowel and an obvious consonant cluster, CC, is interpreted as a vowel plus a consonant:

VSCC /sumbuwét/ *a personal name;* /sumbuwan/ *wick.*

(*f*) A single high vocoid that occurs between an obvious consonant and silence is interpreted as a vowel:

CSϕ All words ending in the unaccented suffixes /-u/ first person singular; /-i/ second person singular. /nawahu/ *my feelings;* /malabi/ *cut it.* (Compare /labih/ *old;* /qabiq/ basket).

(*g*) A single high vocoid preceded by silence and followed by an obvious consonant is interpreted as a consonant plus homorganic vowel:

ϕSC /ying/ *cat.* (Compare /qinget/ *perspiration;* /hingol/ *sway*).

(*h*) If a cluster of two high vocoids occurs between an obvious consonant and an obvious vowel or silence, the high vocoid contiguous to the obvious consonant is interpreted as a vowel, and the other high vocoid is interpreted as a consonant:

CSSϕ /kanguy/ *stem;* /naquy/ *visit.*
ϕSSC /yufuy/ *small worm;* /yuh/ *you* (plural).
VSSC /kelawih/ *when;* /bensewit/ *chips;* /dowin/ *loincloth;* /heyuh/ *good;* /keyubug/ *type of tree.*
CSSV /miwas/ *pass by;* /qiwúng/ *left hand;* /huyúw/ *plate;* /kuyag/ *life;* /quyúh/ *forehead.*

(*i*) If a cluster of two high vocoids occurs between two obvious single consonants, the first high vocoid is interpreted as a consonant if it is nonsyllabic, and as a vowel plus consonant if it is syllabic and long. The second high vocoid is interpreted as a vowel:

CS:SC /suwiq/ *wrong* /tuwil/ *prying tool;* /siyufun/ *centipede;* /miyuf/ *puff out.*
CSSC /henyulam/ *clothes;* /belyung/ *hatchet;* /legwih/ *wild fruit.*

(*j*) If a cluster of two high vocoids occurs contiguous to an obvious vowel and silence, the high vocoid contiguous to the obvious vowel is interpreted as a consonant and the other high vocoid is interpreted as a vowel plus consonant:

VSSϕ /méyuw/ *spirit.* (Compare /heyuh/ *good*).

(*k*) If a cluster of three vocoids occurs between two obvious single consonants, the first and third high vocoids are interpreted as vowels and the second as a consonant:

CSSSC /buyus/ *spear;* /duyung/ *moth;* /luyung/ *large root;* /beluyut/ *basket;* /siwih/ *carry a baby.*

ACCENT AND INTONATION

4.1. Accent.

Accent occurs on the final syllable of the majority of word bases. In these cases it manifests itself as stress. Stem final stress is not altered by affixation.

In a small number of word bases accent occurs on the penultimate syllable. It is of interest that the only cases of penultimate accent so far observed are in eight words with both syllables containing /e/, but not all words with /e/ in both syllables are so accented. The penultimate vowel, when accented, is lengthened and both syllables seem to receive equal stress. (Orthographic note: Word final accent is left unmarked. Penultimate accent is marked /ê/ to save confusion with /é/.)

/leged/	*industrious*	/lēged/	*south*
/ketef/	*ten centavos*	/kètef/	*roof*
/tebel/	*to leave behind*	/tèbel/	*boiled water*
/heled/	*tart tasting*	/hèled/	*hoarse*
/melel/	*wait*	/mèlel/	*flow*
/metem/	*set fire to*	/mètem/	*mistrust*
/melem/	*water-logged*	/mèlem/	*rice improperly cooked*
/nelem/	*give more than requested*	/nèlem/	*deep*

4.2. Intonation

Each utterance has one or more intonation units. Though the phonemic status of these units has not been fully analyzed, the contrast between the following five patterns is quite clear. (1, 2, and 3 represent high, mid, and low tones respectively, and 1′ and 3′ represent extra-high and extra-low).

(*a*) Mild emphasis. The accented syllable of the word being emphasized has high tone. Syllables between consecutive high tones and before the first high tone of an utterance have mid tone. The last high tone before a pause is glided to low on succeeding syllables or on the accented syllable itself if that is final.

```
 1–3                                  2  2  2  1  3
Deng. It's finished.                  Laq dengen deng he. It's not finished yet.

 2 1–3                                2 1  3
Halay. Rice.                          Halayu. My rice

 2  1  2  2 1–3                       2 1 2  3
Hemdaw le halay. They are             Múgúwi kúq. Are you going?
      drying the rice.
 2  2  2  3 1–3                       2 1 2  1–3
Hemdaw le halay. They are             Múgúwi kúq. You'll go, won't you?
      drying the rice.
```

(*b*) Strong emphasis. Similar to (*a*) but with a much wider range between high and low tone and a lengthening of the syllable receiving the high tone.

```
 2 1–3'                               2 1'2  3'
Tahu:h That's true!                   Géhéli kun. He says to hurry!
```

(*c*) Anger. All tone levels in the sentence are much higher than normal except the last word; which has a strong-emphasis intonation. In extreme anger the intonation is almost a shrill monotone.

```
 1   1 1 1   1   1   1 1'1 1   1'–3
Tuh Feliduh tuh túq tenibuhen o:h. That Alfredo almost knife me!
```

(*d*) Sarcasm. Similar to (*a*) but the syllable before the accented one has the high tone, and there is a very wide range between high and low tone.

```
 2 1' 3'
Hegemún. Such conceil!

 1' 3'
Bilaw. Cross-eyed. (when mimicking a mispronounciation)
```

(*e*) Incomplete. A low rising intonation occuring clause or utterance final signifies that there is more implied than is

actually said up to that point, or that the speaker has some reservations.

2 3′–3
Nih kemoqen nih . . . *This is what happened . . .*
2 3′–3
Menúm. *It's sweet (but . . .).*

DISTRIBUTION OF PHONEMES

5.1. Vowel phonemes.

The distribution of vowels in two-syllable words was examined by classifying some 1,400 such words. The results are tabulated below as the percentages of words containing each possible pair of vowels. This demonstrates certain restrictions on the distribution of vowels listed in 1.1.

Vowels of second syllable

Vowels of first syllable	i	u	e	a	o	ú	é
i	2	3	2	3	3	2	.
u	3	6	2	3	2	2	2
e	2	5	10	6	5	2	3
a	2	4	.	10	.	.	.
o	2	4	.	.	5	.	.
ú	.	.	.	.	.	3	.
é	.	.	.	.	.	.	2

Vowels appear to be completely unaffected in their occurrence by the contiguous consonants, each of the seven vowels being observed to precede and follow each consonant.

5.2. All consonants occur freely in word initial, word final, and intervocalic positions. However, in word medial consonant clusters, CC, some restrictions have been noted. The first member of a cluster is always a liquid: /l/, /m/, /n/, or /ng/ (except for a small number of Spanish loan words). The second member of a cluster may be any consonant other than /h/ and /q/.

/helngún/ *increase;* /belkon/ *small eyes;* /selbét/ *neighboring;* /demfut/ *spit out;* /kemdol/ *move;* /kemnit/ *blink;* /kemmes/ *squeeze;* /lemsoq/ *come off;* /demlug/ *forceful;* /demyol/ *pull;* /béntéy/ *to watch;* /kenwom/ *trenchmouth;* /belangguq/ *prisoner.*

6. Loan words.

The /p/ of borrowed words almost invariably, even with younger speakers, becomes the Tagabili phoneme /f/. However in four loan words (p) has been infrequently observed in place of the regular /f/:

/fakat/ and /pakat/ *friend* (from Magindanao "pakat")
/fesitah/ and /pesitah/ *20 centavos* (from Spanish "peseta")
/fesénsiyah/ and /pesénsiyah/ *forgive* (from Spanish "paciencia").
/fetedumak/ and /petedumak/ *lamp* (from English "Petromax" trademark).

The /r/ in loan words in initial, word final, and pre-consonantal positions becomes the Tagabili phoneme /l/, while an intervocalic and postconsonantal /r/ usually becomes the phoneme /d/:

the Spanish name "Rivera" becomes /lebidah/
English "tractor" becomes /tdaktul/ or /tedaktul/
English "garden" becomes /galdin/

The sound (dz) has been observed in three words and has been symbolized as /dy/:

/fedyan/ and /fedeyan/ *market* (from Magindanao "padian")
/hedyal/ and /hedeyal/ *a stone game*
/dyalamin/ *eye glasses* (from P.M.P. *caremin)

A SUGGESTED ORTHOGRAPHY

7.1. For an orthography of Tagabili two modifications are suggested to the phoneme symbols used in this paper:

Glottal. In word final position glottal stop is indicated by a grave accent (ˋ) over the vowel of the final syllable. In word initial and intervocalic positions it is not written in the suggested orthography, so as to conform to the Filipino National Language.

/h/ in word final position is not written (though it is always written before a suffix) for two reasons: (*a*) word final /h/ disappears in utterance medial position, and (*b*) word final /h/ is rare in the Maitum dialect, which has the greatest number of literate Tagabilis.

7.2. The digraph /ng/ has been employed for ease of typing and to conform to the National Language. In the suggested orthography and in previous Tagabili publications,[7] it has not

[7] Previous Tagabili publications are First Primer, the Pepe series, The Little Red Hen, The Old Woman And Her Pig, and the Tagabili Vocabulary. These were prepared by Alice Lindquist and Vivian Forsberg, and were published during the years 1954–55 by the Summer Institute of Linguistics, Manila.

been considered essential to maintain the distinction between the phoneme /ng/ and the two-phoneme sequence /n.g./ (See Section 2.3), as so few words are involved.

7.3. The orthography suggested here differs in several respects from the orthographies used in previous Tagabili publications, and also from the orthography of the neighboring Bilaan language.[8]

/e/ is used for the pepet vowel to conform to other major Philippine languages.

/é/ with its diacritic, is used for the mid front vowel, as this phoneme occurs only one-tenth as frequently as pepet.

/ú/ is used for the mid back vowel in place of previous /ó/ for two reasons: (*a*) there is considerable free variation between this phoneme and /u/, and (*b*) in the Maitum dialect literates have already chosen to write this phoneme as /u/.

/o/ is used for the low back vowel in preference to Bilaan /á/ for two reasons: (*a*) the Tagabili sound is closer to the mid back vowel than to the low central vowel, and (*b*) literates have already chosen to write this phoneme as /o/.

A comparison of the several orthographies is set out in the following table:

Tagabili.

Orthography of primers	i	e	ʌ	a	o	o	u
Orthography of vocabulary	i	e	ʌ	a	o	ó	u
Suggested orthography[9]	i	é	e	a	o	ú	u

Bilaan.

First orthography	i	e	ʌ	a	ɑ	o	u
Revised orthography	i	é	e	a	á	o	u

ILLUSTRATIVE TEXT

BONG BUSAW (BIG SPIRIT)

1. Lemwút bong busaw neqe diyoh lem linuh. (leave big spirit and bathe in deep-place-of-river) 2. Ne qigoqen diyoh tonen tey qutún nuq lem qél. (and while/he bathe saw/he intensifier fish there in river). 3. Mon bong busaw, Qétey qutún nih de? (said big spirit exclamation fish this interrogative) 4. Kendol ne nuwahu duléhu. (never mind now get/I fishhook/my) 5. Lemwút bong busaw mulék qebeq gunuq.

[8] Dean, James C. Phonemes of Bilaan. Philip. Jour. Sci. 84 (1955) 311–322.

[9] Because of adverse reactions from readers of Tagabili to the diacritics and in order to facilitate printing, as an experiment the digraphs /ea/ and /oa/ have been substituted for /é/ and /ú/ respectively in the latest series of graded primers (1957).

(leave big spirit return direction/to house) 6. Nuwahen duléhen ne teluh goyuh soging genulon. [get/he fishhook/his and three stalk banana (species)] 7. Moq fan duléhen. (make bait fishhook/his)

8. Ne kúl dituh tah botuh. (and arrive there top rock) 9. Ne nefanen duléhen luwuh fék soging genulon. [and bait/he fishhook/his two hand banana (species)] 10. Boten qelem linuh. (throw-out/he direction/in deep-place-of-river) 11. Mon bong busaw, Sekotem qutún bong kemlúf yúquh. (said big spirit grab/you fish big glide-up that/specific) 12. Ne kúl dituh yem duléh. (and arrive there that fishhook) 13. Laq but tonen duh soging. (negative again see/he it banana) 14. Deng mem ken qutún bong. (finished thoroughly eat fish big) 15. Bud sekot bong busaw yúh duléhen. (again yank big spirit that fishhook/his) 16. Ne bong busaw, Hennagawen fan duléhu. (and big spirit steal/he bait fishhook/my)

17. Bud nuwahen teluh fék soging genulon. [again get/he three hand banana (species)] 18. Bud sekot bong busaw duléhen. (again yank big spirit fishhook/his) 19. Bud nefanen segoyuh soging genulon. [again bait/he one-stalk banana (species)] 20. Bud boten qetuh qelem linuh. (again throw-out/he direction/there direction/in deep-place-of-river) 21. Bud salaq kesekoten duh. (again miss grab/his it) 22. Bud hennagawen fanen. (again steal/he bait/his) 23. Laq ne tek sotuh goyuh duqen. (negative now only one stalk yet/it) 24. Bud nefanen duléhen. (again bait/he fishhook/his) 25. Mon bong busaw, Qétey helayam nih de deng gotuh fanu. (said big spirit exclamation trouble this interrogative finished all bait/my) 26. Belat nawahen. (heavy breath/his)

27. Mulék qebcq gunuq. (return direction/to house) 28. Senúluk yehenen, Nuq se duh bong busaw. [ask wife/his where (meaning undetermined) it big spirit] 29. Gutahem kut utún. (catch/you our-dual-inclusive fish) 30. Ofol douh hemgagid moq ken tegamahu kúm. (think I more-than-enough make food save you) 31. Moqen nih duh ke laqen duq gutahem. (why this it if negative/it yet catch/you) 32. Kelwút yehen bong busaw nuwahen dek. (leave wife big spirit get/she pestle) 33. Benogulen bong busaw. (beat/she big spirit) (34. Ne túdúq beq kuluhen. (and right on head/his) 35. Túdúq metafiq bong busaw. (immediately die-suddenly big spirit)

FREE TRANSLATION

1. Big Spirit went to bathe in the deep part of the river. 2. While he was bathing he saw a huge fish in the water. 3. Big Spirit said, Wow! What kind of fish is this? 4. Never mind; I'm going to get my fishhook. 5. So Big Spirit returned to his house. 6. He got his fishhook and three stalks of the long, green bananas. 7. That would be the bait for his fishhook.

8. When he got back to the river he went to the top of a large rock. 9. He baited his fishhook with two hands of bananas. 10. He threw it out into the deep part of the river.

11. He called out, swim up, big fish, and grab that! 12. Later he went back to the fishhook. 13. He couldn't see the bananas. 14. The huge fish had eaten them. 15. Big Spirit yanked in his fishhook. 16. He said, He stole the bait from my fishhook!

17. Again he got three hands of bananas. Again Big Spirit yanked in his fishhook. 19. Again he baited his hook with one stalk of bananas. 20. Again he threw it out into the deep part of the river. 21. Again the fish got away. 22. Again it had stolen his bait. 23. This will never do! There is only one stalk left! 24. Again he baited his fishhook. 25. Big Spirit said, What trouble I'm having! Every bit of my bait is gone! 26. He felt very despondent.

27. He returned home. 28. His wife asked, Where is it, Big Spirit? 29. Where is the fish you caught for us? 30. I have a large amount of rice prepared and set aside for you. 31. Why didn't you catch something? 32. The wife of Big Spirit went to get the pestle. 33. She beat Big Spirit. 34. She beat him right on the head. 35. Big Spirit died immediately.

APPENDIX

9.1. Technical definition of phonemes.

/u/. High close back rounded vocoid.
/ú/. Mid close back rounded vocoid.
/o/. Low close back rounded vocoid.
/e/. Mid open central unrounded vocoid.
/a/. Low open central unrounded vocoid.
/i/. High close front unrounded vocoid.
/é/. Mid front unrounded vocoid, both close and open allophones.
/t/. Voiceless unaspirated alveolar stop.
/d/. Voiced unaspirated alveolar stop.
/b/. Voiced unaspirated bilabial stop.
/k/. Voiceless unaspirated velar stop.
/g/. Voiced unaspirated velar stop.
/q/. Glottal stop.
/s/. Voiceless grooved alveolar fricative.
/f/. Voiceless flat labiodental fricative.
/h/. Voiceless glottal fricative.
/m/. Voiced bilabial nasal.
/n/. Voiced alveolar nasal.
/ng/. Voiced velar nasal.
/l/. Voiced clear alveolar lateral.
/w/. Voiced labial semi-vowel.
/y/. Voiced palatal semi-vowel.

9.2. Syllable pattern symbols.

C = consonant
V = vowel
S = semi-vowel
ϕ = silence
: = length

9.3. The development of the seven phonemic vowels in Tagabili.

Although a phonemic analysis is not based upon comparative materials, it is nevertheless of interest to inquire how the Tagabili system of seven vowel phonemes developed from the four vowel system reconstructed for Original Austronesian (Proto–Malayo–Polynesian).

/e/ versus /u/.

From a study of some 150 probable cognates, it was found that /a/, /e/ (pepet), /i/, and /u/ correspond in the majority of cases to *a, *e, *i, and *u respectively.[10]

*pipi (h)	hifih	*cheek*	*pirak	filak	*money*
*baRa(h)	balah	*embers*	*pusej	huhed	*navel*
*qulu	kuluh	*head*	*gelaN	gelang	*bracelet*
*deket	deket	*glue*	*ujiN	qusing	*charcoal*

However *a in the penultimate syllable became /e/ if the final syllable contained *e:

*Dalem	delem	*below*	*qatep	ketef	*roof*
*ha(n)teD	qeted	*deliver*	*tazem	telem	*sharp*

/é/ appears to have developed from *i in the final syllable in two kinds of circumstances:

(*a*) Final *iq became /ék/, with or without vowel harmony:

*piliq	mélék	*choose*	*beniq	bének	*seed*
*pe(dD)iq	hedék	*to smart*	*sepiq	sefék	*strip*
*putiq	huték	*white*	*muliq	mulék	*return*

(*b*) *Vi contracted to /é/:

*bei	béh	grandmother	*wa(hO)iR	qél	*water*

[10] An asterisk is placed before reconstructed phonemes and words. Reconstructions are from Dempwolff and Dyen in Dyen's orthography.

/o/ appears to have developed from two sources:

(*a*) *a in the penultimate syllable became /o/ if the final syllable contained *u:

*(qO)asu(h)	qohuh	*dog*	*batu(h)	botuh	*stone*
*Dahun	doqun	*leaf*	*balu(h)	boluh	*widowed*
*qanTuk	kotuk	*nod*	*Ra(m)bun	lobun	*cloud*
*manuk	qonuk	*chicken*	*kayuh	koyuh	*tree*
*qasu(h)	kohuq	*fireplace*	*apuy	qofih	*fire*

(*b*) *u in both syllables became /o/ if the word had final *q or *k:

*bunuq	bonok	*kill*	*suluq	solok	*light*
*tubuq	towok	*grow*	*pusuq	hosoq	*heart*
*Rusuk	lohok	*rib*	*tu(n)Zuq	tolok	*show*
*buRuk	bolok	*rotten*	*puluq	-foloq	*ten*

/ú/ appears to have developed from *a in the final syllable when this was followed by a nasal and preceded by *u in the penultimate:

*qutaN	qutúng	*credit*	*quban	qubún	*grey hair*
*bulan	bulún	*moon*	*quZan	kulún	*rain*

SCREENING OF PHILIPPINE MEDICINAL PLANTS USED IN THE TREATMENT OF TUBERCULOSIS FOR SUBSTANCES INHIBITORY TO MYCOBACTERIUM TUBERCULOSIS 607

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The presence of antibacterial substances in higher plants has been previously investigated. Of 161 plants examined by Gottshall, et al.,(4) 127 were found active against *Mycobacterium tuberculosis* H37 in the absence of blood. In examining 310 species, Fitzpatrick(3) likewise found that extracts from 22 plants in a dilution of 1:80 or higher inhibited the growth of the same strain of tubercle bacillus. Azarowicz, et al.(1) tested 548 plant extracts against *Mycobacterium tuberculosis 607* and found 12 per cent to be antimycobacterial in the presence of serum. It is significant that although many of the plants studied by these investigators were not medicinal, a few of these were found to possess antimycobacterial properties.

In the Philippines from time immemorial many species of plants have been utilized by the people, especially those in the rural areas, for the cure of tuberculosis. Quisumbing(6) has recorded 49 plants identifying the particular parts thereof that are used for this purpose. Sulit(8) has reported seven species as having the same application, two of which are also included in Quisumbing's list. In view of the popular use of these plants as tubercular remedies, the authors, in undertaking their present study, assumed that most of them would have the active principle inhibitive of the growth of the tubercle bacillus.

MATERIALS AND METHODS

A total of 45 plants were used in this investigation. Of the plants listed by Quisumbing, only 40 were studied due to failure to obtain samples of the rest. The other five plants were from Sulit's list, which did not originally appear in Quisumbing's.

Samples from the parts described as useful in the treatment of tuberculosis were obtained from the fresh plants studied.

Where other parts were not available, the leaves were used. From these samples, extracts were obtaind by macerating the parts in alcohol, water, ether, petroleum ether, chloroform, acetone, or dilute acetic acid. In collecting and sampling the plant materials and in preparing and assaying the extracts, the same procedures used in the general study of other higher plants for antibacterial substances described in a previous paper(5) were followed.

In the extraction, after macerating the samples for 24 hours at room temperature, the extracts were filtered and then tested for the presence of antimycobacterial substances with the use of the modified filter-paper-disc-agar-plate method. In this method, 4 cc of liquefied glycerol agar seeded with 2 per cent 4-day old culture of *M. tuberculosis 607* in glycerol broth was evenly poured into each petri dish containing 10 cc of solidified glycerol agar. The plates were incubated at 37°C for one hour prior to placing the filter discs saturated with the test extract on the seeded agar. After 48 hours of incubation at 37°C, antimycobacterial activity was determined by observing the presence or absence of halo zones of inhibition of the test organism and by measuring their sizes.

RESULTS AND DISCUSSION

The results obtained from 313 extracts prepared from the plants locally used in the treatment of tuberculosis and examined for activities against *Mycobacterium tuberculosis 607* are shown in Table 1. As this table shows, evidence of the presence of the inhibitory substances of varied potency against *M. tuberculosis 607* was observed in extracts of 38 out of 45 plants examined. The active principles in 26 of these species were extracted by two or more solvents, while in the other 9, by only 1. In the latter case, that of *Gossamphynus heptaphylla, Fiscus elastica,* and *Drynaria guercifolia* were extracted only by alcohol; that of *Punica granatum, Bryophyllum pinnatum* and *Biophytum sensitivum,* only by water; that of *Bambusa vulgaris* and *Abrus precatorius,* only by chloroform; and that of *Premna odorata,* only by dilute acetic acid.

The results indicate that water, the usual solvent used by the common people in preparing the local antitubercular remedy, is capable of extracting the antitubercular substances only from 20 species, of which 13 showed complete inhibition of *M. tuberculosis 607*; 6, partial; and 1, slight indication. The

TABLE 1.—*Activity of plant extracts against Mycobacterium tuberculosis 607.*

Common and scientific name	Part examined	Zone of inhibition of *Mycobacterium tuberculosis 607* in mm. [1]						
		Alcohol extract	Aqueous extract	Ether extract	Petroleum ether extract	Chloroform extract	Acetone extract	Acetic acid extract pH4.
Alagasi [*Leucosyke capitellata* (Poir.) Wed.]	Leaves	++13.5	++13.5	+++14.0	0	++13.5	+++14.0	++13.5
Alagaw (*Premna odorata* Blanco)	Leaves	0	0	0	0	0	0	+15.0
Aroma [*Acacia farnesiana* (Linn.) Willd.]	Leaves	+++17.6	+++13.5	0	0	0	+++30.5	++++31.5
Asparagus (*Asparagus officinalis* Linn.)	Roots	+++13.5	+++13.5	++13.5	0	++13.5	0	++13.5
Bael (*Aegle marmelos* Correa)	Leaves	0	0	0	0	0	0	0
Balabat (*Licuala spinosa* Wurmb.)	Leaves	+13.5	0	0	0	+13.5	0	0
Bankoro (*Morinda citrifolia* Linn.)	Leaves	0	0	0	0	0	0	0
Palutan [*Flacourtia indica* (Wurm. f.) Merr.]	Leaves	+14.0	++20.0	0	0	0	0	+13.5
Bogo [*Garuga abilo* (Blanco) Merr.]	Leaves	0	0	0	++13.5	++13.5	0	0
Buboi-gubat [*Gossampinus heptaphylla* (Houtt.) Bakh.]	Leaves	+15.0	0	0	0	0	0	0
Bulak-damo (*Asclepias curassavica* Linn.)	Leaves	+13.5	0	0	0	+14.0	0	0
Butuan [*Musa errans* (Blanco) Teodoro var. *Botoan* Teodoro]	Shoot	0	+++13.5	0	+16.0	+15.0	0	----------
Canela (*Cinnamomum zeylanicum* Blume)	Leaves	0	+++13.5	0	0	++13.5	0	+++13.5
Cham-poi (*Myrica rubra* S. and Z.)	Leaves	0	0	0	0	0	0	0
Garlic (*Allium sativum* Linn.)	Bulbs	+++13.5	0	0	++13.5	++18.0	0	0
Granada (*Punica granatum* Linn.)	Roots	0	+++14.0	0	0	0	0	0
Gulaman (*Gracilaria* sp.)	Dried plant	++13.5	0	0	+13.5	+++13.5	0	0
Indian rubber tree (*Ficus elastica* Roxb.)	Leaves	+++15.0	0	0	0	0	0	0
Kalingag (*Cinnamomun mercadoi* Vidal)	Leaves	0	++13.5	0	0	++13.5	++13.5	++13.5
Kalumbibit (*Caesalpinia crista* Linn.)	Seed	++13.5	++13.5	++13.5	++13.5	+++13.5	++13.5	++13.5

[1] Inhibitive activity against test organism: +++, for complete inhibition; ++, for partial inhibition; +, for slight indication of inhibition; O, for negative inhibition. The number refers to the diameter of the halo zone in millimeters.

TABLE 1.—*Activity of plant extracts against Mycobacterium tuberculosis 607.*—Continued.

Common and scientific name	Part examined	Zone of inhibition of *Mycobacterium tuberculosis 607* in mm.[1]						
		Alcohol extract	Aqueous extract	Ether extract	Petroleum ether extract	Chloroform extract	Acetone extract	Acetic acid extract pH4.
Katakataka [*Bryophyllum pinnatum* (Lam.) Kurz.]	Leaaes	0	+++13.5	0	0	0	0	0
Kawayan (*Bambusa spinosa* Blume)	Leaves	0	+++40.0	+++20.0	0	+++19.0	0	----------
Kawayan kiling (*Bambusa vulgaris* Schrad.)	Leaves	0	0	0	0	+15.0	0	0
Kondol [*Benincasa hispida* (Thurg.) Cogn.]	Fruit	0	----------	0	+13.5	+++13.5	0	----------
Lagtang [*Anamirta cocculus* (Linn.) W and A.]	Leaves	0	+13.5	++13.5	0	0	0	+13.5
Lagunding-dagat (*Vitex trifolia* Linn.)	Leaves	+14.0	0	+++15.0	++14.0	+++14.0	++14.0	0
Lettuce (*Lactuca sativa* Linn.)	Leaves	0	0	0	0	0	0	0
Linga (*Sesamum orientale* Linn.)	Seed	+++13.5	+++13.5	0	0	0	0	0
Luya (*Zingiber officinale* Rosc.)	Rhizomes	0	+++20.0	+++13.5	+++13.5	++16.5	+++13.5	+++13.5
Makahiyang-lalaki [*Biophytum sensitivum* (Linn.) DC]	Leaves	0	++14.0	0	0	0	0	0
Mulberry (*Morus alba* Linn.)	Leaves	++15.0	0	0	0	++13.5	++14.2	0
Niyog (*Cocos nucifera* Linn.)	Meat	0	----------	0	+13.5	+13.5	0	+13.5
Paco [*Drynaria quercifolia* (Linn.) J. Smith]	Leaves	++13.5	0	0	0	0	0	0
Parol-parolan (*Cardiospermum halicacabum* Linn.)	Leaves	0	0	0	0	0	0	0
Payang-payang [*Flemingia strobilifera* (Linn.) R. Br.]	Leaves	0	+++19.0	0	0	++15.0	0	0
Saga (*Abrus precatorius* Linn.)	Leaves	0	0	0	0	+16.0	0	0
Saluyot (*Corchorus capsularis* Linn.)	Stem and Leaves	+++13.5	0	++13.5	0	++17.5	0	0
Santan-pula (*Ixora chinensis*)	Flower	+++13.5	+++13.5	+14.0	+++15.0	+16.0	++14.0	----------
Sibuyas (*Allium sepa* Linn.)	Bulbs	++14.0	++15.0	+++14.0	+++13.5	+++13.5	0	+++13.5
Siempreviva [*Kalanchoe laciniata* (Linn.) DC.]	Leaves	0	++15.0	0	0	++13.5	0	+++14.0
Tagulauai [*Parameria laevigata* (A. Juss.) Moldenke]	Leaves	0	0	0	0	0	0	0
Tagulinau [*Emilia sanchifolia* (Linn.) DC.]	Leaves	+++13.5	+++16.0	++13.5	0	0	0	+++13.5
Teak (*Tectona grandis* Linn. f.)	Leaves	+++28.0	0	+++26.0	+++15.0	+++20.0	+++27.0	0
Tigre (*Phalaenopsis schilleriana* Reich. f.)	Leaves	++13.5	0	0	0	++13.5	0	0
Water cress (*Nasturtium officinale* R. Br.)	Leaves	0	0	0	0	0	0	0

[1] Inhibitive activity against test organism: +++, for complete inhibition; ++, for partial inhibition; +, for slight indication of inhibition; O, for negative inhibition. The number refers to the diameter of the halo zone in millimeters.

aqueous extract of *Bambusa spinosa* and *Zingiber officinale* produced complete and wide zones of inhibition of the test organism. The inhibition produced by *Flacourtia indica* was partial but wide.

Twenty-one alcoholic extracts exhibited varying degrees of inhibition of *M. tuberculosis 607,* complete with nine, partial with seven and slight indication with five. Extracts of *Tectona grandis* produced complete and wide zone of inhibition of the same test organism.

Ether extracts of 12 plants inhibited the test organism in varying degrees as follows: complete inhibition of the test organism in 7, partial in 4, and slight indication in 1. Extracts of *B. spinosa* and *T. grandis* exhibited complete and wide zone of the same test organism.

Twelve petroleum ether extracts were found to be active against the test tubercle bacillus. Four of them showed complete inhibition; four, partial; and four, slight; but none of the zones produced were wide.

Chloroform was superior to other solvents in extracting the antitubercular substances. Extracts from 26 samples exhibited varying degrees of inhibition. Seven of them produced complete inhibition; seven, slight; and 12, partial. Extracts from *T. grandis* exhibited complete wide zone of inhibition.

Acetone extracts of 9 species were found active against the test organism. Four of them caused complete and 5 partial inhibition. Complete wide zones of inhibition were produced by extracts of *Acacia farnesiana* and *T. grandis.*

Thirteen of the acetic acid extracts showed varying degrees of inhibition of the test organism. Five of them showed complete inhibition; three, partial; and five, slight. The extract from *A. farnesiana* exhibited complete wide zone of inhibition.

Acacia farnesiana, Bambusa spinosa, Zingiber officinale, and *Tectona grandis* were found to contain potent antitubercular substances that merited further study. The negative reaction shown by the seven species should not yet be taken as proof of the absence of antimycobacterial substance. Seasonal variation might have a role in this particular case. Experience has shown that *Samanea saman* extract prepared from leaves in the month of February when tested against *M. tuberculosis 607* showed complete wide zone of inhibition, but those prepared

in the month of July showed negative results, unless so concentrated that 1 cc of it represents 1 gram of leaves.

The results of the study seem to indicate that many of the plants really contain curative substances for the malady. To substantiate this observation, however, it would be necessary to know the medicinal significance of the purified active substance, by conducting a comparative test of its efficacy *in vivo* with that of known tubercular drugs.

SUMMARY

1. Three hundred fifteen extracts from 45 medicinal plants locally used for the treatment of tuberculosis were screened for the presence of substances inhibitory to *Mycobacterium tuberculosis 607*.

2. With the use of seven solvents for extracting the antibacterial substances, 38 of the 45 plants examined were found to possess antimycobacterial properties.

3. Under each extractive the number of plant species found to possess antimycobacterial activities may be arranged as chloroform, 26; alcohol, 21; water, 20; acetic acid buffered to pH 4.1, 13; ether, 12; petroleum ether, 12; and acetone, 9.

4. The species possessing marked antagonistic effect on the test organism *M. tuberculosis 607* are *Acacia farnesiana, Bambusa spinosa, Zingiber officinale,* and *Tectona grandis.*

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WATER-SOLUBLE EXTRACT FROM COCONUT HUSK AND ITS APPLICATION IN LEATHER TECHNOLOGY

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Among the useful plants in the Philippines, the coconut is probably the most versatile, considering that nearly all its parts are utilizable. From its roots to its leaves, hundreds of products of one form or another are obtained.

The average yield from the tree in the Philippines alone is estimated to be more than 4 billion nuts [1] yearly. From the matured nuts, copra, from which oil is derived and which forms its main product, is produced. In 1953, the production of copra reached 816,300 metric tons with a value of ₱204,075,000. In fact the copra industry constitute the biggest dollar-earning industry of the country on which one-third of the Filipino people depend largely for their subsistence.

The husk, or outer covering of the nut, comprises about 23 per cent of the whole fruit and consists mostly of fibrous material embedding the coir. As one of the most important by-products of the copra industry, it is generally left alone as a waste product for lack of use for it. By way of preventing this wastage in the material, attention was directed to the by-product as a possible source of tanning and dyeing material.

The extraction of good tanning materials from local sources has been the subject of previous investigations. Salcedo and Escalera [2] proved that kamachile bark is one of the best sources of tannin for use in the local leather industry. Baens [3] made a similar study on tannin from the kernels of green betel nuts. These, too, produced fine material for tanning leather. Baens, et. al.,[4] also determined the tannin content of several species of Philippine barks and woods with very promising results.

Coconut husk has previously been used with apparent success by leather manufacturers of Meycawayan Municipality, Bulacan Province, to effect tanning of leather. They simply immerse the husk with the hide in water and after a couple of days they produce leather that is dyed and partly tanned. Their method is comparatively crude and the amount of tannin obtained can not compare with other tanning materials.

[1] Data furnished by the Philippine Coconut Administration.
[2] Nat. Appl. Sci. Bull. 12 (1952) 226.
[3] Philip. Jour. Sci. 75 (1941) 363–367.
[4] Philip. Jour. Sci. 55 (1934) 177–190.

EXPERIMENTAL PROCEDURES AND RESULTS

Preparation and analyses of coir dust.—Comparatively dry coconut husks obtained from matured nuts were used in this investigation. The husks were cut into small pieces and the fibers were carefully separated from the coir dust by hand. The dust obtained, which was free of even the smallest fibers, was analyzed according to the Methods of Analysis of the Association of Official Agricultural Chemists.

Coconut coir dust derived from a commercial defibering machine of the Philippine Coconut Administration from whose workshop the dust was kept in bins exposed to the sun and rain was also obtained. This coir dust was dried and passed through a 30-mesh sieve and analyzed similarly.

The results of our analyses together with the analysis of Salcedo and Escalera of ground kamachile bark are shown in Table 1.

TABLE 1.—*Composition of coconut coir dust and kamachile bark.*

	Coconut coir dust			Kamachile bark (ground)
	Without fibers[1]	With fibers[2]	Water soluble extract	
	Per cent	*Per cent*	*Per cent*	*Per cent*
Moisture	11.8	9.9	10.3	11.1
Ash	3.5	5.2	32.8	4.0
Total solids	88.2	90.1	89.7	88.9
Soluble solids	25.7	15.3	83.5	34.8
Insoluble solids	62.5	74.8	6.2	54.1
Tannin	11.4	8.4	19.2	25.4
Non-tannin	14.3	6.9	64.3	9.4
Nitrogen[3]	3.1	3.2	2.8	5.7

[1] Prepared by hand from dry husks.
[2] Obtained from a commercial defibering machine.
[3] Calculated as protein.

Coconut coir dust obtained from the defibering machine and stored in open air contain less tannin than coconut husk coir dust from which all fibers had been removed, rain water having apparently washed away part of the tannin content of the former. Compared with the kamachile bark, however, both contain only about one-third as much tannin.

A comparative study of the composition of both coconut coir dust from which all fibers had been removed and of ground coconut husk, was also made to determine definitely which of the two is the better source of tannin. The coir dust was found to contain more tannin, as shown in Table 1.

Preparation and analysis of water-soluble extract.—Boiling water amounting to about ten times the weight of the coir dust was added to the material and the mixture was allowed to macerate for 3 weeks. After this period, the macerated coir dust was pressed and the solution obtained was filtered. The solution was allowed to evaporate until a thick syrupy liquid was obtained. The liquid was then placed in an oven to dry until it could be made into the fine powder, forming our water-soluble extract. This was analyzed following the modified hide-powder method. As shown in Table 1, the powdered water-soluble extract has a much higher tannin content than either of the two coir dust samples, and compares favorably with ground kamachile bark.

Application of water-soluble extract.—A piece of hide obtained from a tannery in Meycawayan Municipality, Bulacan Province, was used in this experiment. The salting, unhairing, fleshing and splitting of the hide were done in the said tannery, while the deliming, washing and pickling were accomplished in the National Institute of Science and Technology Leather Technology Laboratory.

The hide was soaked in a definite amount of boiled water containing 20 per cent powdered extract and 10 per cent sodium chloride. After the solution had completely penetrated the hide, sulfonated castor oil was added and the immersion was allowed to stand for four days. After this period the hide was removed from the solution and dried in air. The leather, which was completely dyed and satisfactorily tanned, was found suitable for use as sole leather.

SUMMARY

From the coconut, probably the most versatile among the useful plants in the Philippines, hundreds of products of one form or another are obtained. From the nuts copra, which constitutes the mainstay of the biggest dollar-earning industry on which one-third of the people depend, is obtained. Of its by-products, however, the husk, which comprises 23 per cent of the whole fruit, mostly go to waste for lack of use for it. Attention was directed to the material as a possible source of tannin by way of preventing this wastage.

Analyses of the water-soluble extract obtained from the coconut coir dust or fiber show that it compares favorably with tannin from kamachile bark. Although the percentage

of tannin obtained from the coir dust is much lower, coir dust has the advantage over kamachile bark because of its availability and cheapness.

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LAGIKWAY—A HITHERTO UNRECORDED PHILIPPINE PLANT

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A plant which has hitherto been unrecorded in Philippine botany is the common leafy vegetable which is locally known as *lagikway* in Tagalog, especially in Laguna and Quezon provinces; *lagikway malaguhon* in Hanunóo (Mindoro); and *glikway-lakwis, glikway glumawag,* and *glikway-glikug gued* in Subanon (Mindanao).

Although lagikway is rather common all over the islands, authorities on Philippine botany have failed to notice its presence here and to record it in the literature. Blanco, the famous friar-botanist, makes no mention of it in his monumental work both in its first edition [1] and last edition [2] published under the editorship of Vidal y Soler. Merrill who devoted the best years of his life in the study of Philippine plants missed to record it in his compilation,[3] and the same oversight was made by Brown in failing to include it in his latest work.[4]

The wide distribution of lagikway in the Philippines has been confirmed in recent years by botanists and collectors. Mamerto D. Sulit, formerly chief of the Division of Botany, Philippine National Museum, personally informed the writer that as early as 1914 he had known lagikway to have been cultivated for food in Luisiana, Laguna, and the same plant is sold to this day as leaf vegetable in the markets in Sariaya, Quezon. He also found the plant cultivated for food in Loquilocon, Wright, Samar, during a botanical trip to the island in 1948. For lack of flowers or fruits, he was not able to collect specimens of the plant. Gregorio E. Edaño, a veteran collector for Doctor Merrill, had witnessed the planting of the plant in many farms in the country. Neither did he gather specimens of the plant for not finding it with flowers. Edaño estimates the plant to have been growing in the country for some time in the past.

The first botanical collection of lagikway submitted to the Philippine National Museum was made by Dr. Harold C. Conklin, anthropologist from Harvard University and Columbia

[1] Flora de Filipinas. Manila (1837) 887p.

[2] Flora de Filipinas. Gran edicion. Manila (1877–80) 4 vols. (text) + 2 vols. (plates).

[3] An Enumeration of Philippine Flowering Plants. Manila (1925–26) 4 vols.

[4] Useful Plants of the Philippines. Manila (1944–46) 3 vols.

University, who made an ethnobotanical study of plants used by the Hanunóos in Mt. Yagaw, Oriental Mindoro, in 1953. Doctor Conklin's specimens, however, did not throw much light on the classification and identification of the plant, as neither did they have flowers.

Another collection of the plant, this time with flowers, was submitted on January 12, 1954, by Dr. Valente Villegas of the College of Agriculture at Los Baños, Laguna. The mother plant was obtained from a farmer in Tagkawayan, Quezon, and was planted in the college ground. Left alone without plucking its leaves, the plant flowered profusely. Three years later, Charles Frake, an American student of linguistics, sent for identification three specimens without flowers from Dikus, Zamboanga del Norte, in Mindanao.

Lagikway responds very well to planting by cuttings. It adapts itself well to local conditions, given good soil and care. It is generally planted during the beginning of the rainy season in May or June. Cuttings, a foot long or longer, are made from the mature branches or stems and stuck into previously loosened soil in a slanting position one at a time at intervals of 3 meters or more. In the absence of rain, they should be well watered until saplings or small branches appear. Weeds should not be allowed to interfere in its growth.

After about six months the plant becomes profusely covered with leaves, which may then be plucked for food. To allow the plant to develop its big yellow flowers for their ornamental value, the leaves should be left unplucked to keep the plant vigorous and healthy. In a year or more, the plant will bear flowers and then fruits.

The plant may also be regenerated sexually. The seeds are first planted in a seedbed or seedbox until they are germinated. As soon as they reach a height of about 15 cm, the seedlings are transplanted into the field. In the field, the plants should be protected against rodents, insects, and fungus diseases. Like most garden ornamentals, lagikway grows easily with diligent care.

Because of its wide regional distribution and because it has always been found cultivated even among the non-Christian peoples in very remote places in the Philippines, the writer believes that lagikway was introduced into the Philippines, probably by Chinese traders, long before the arrival of the

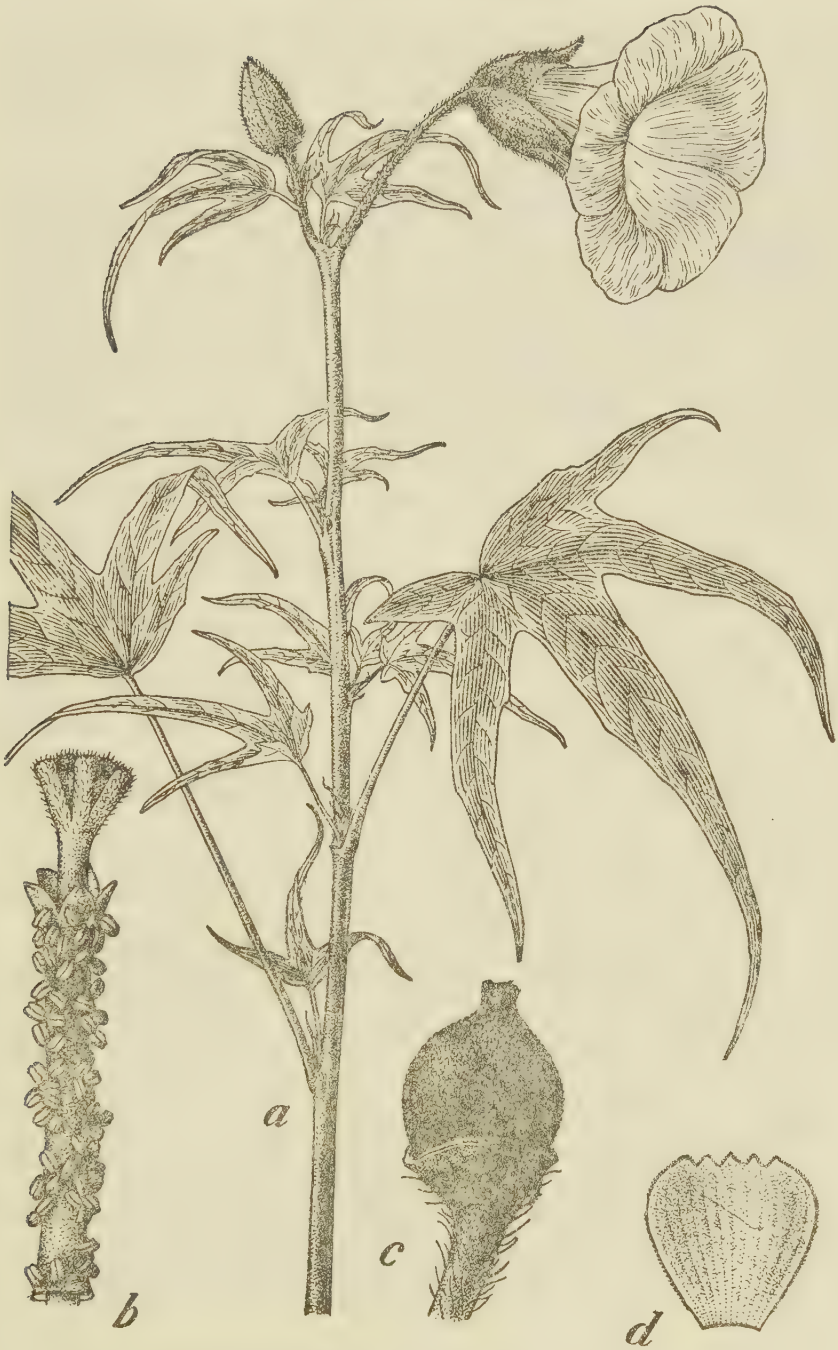

FIG. 1. *Abelmoschus manihot* (Linn.) Medic. ssp. *manihot* fo. *speculatus* (Bakh.) Borss. *a*, Habit showing leaves, bud, flower, and stipules, × ½; *b*, staminal tube with the style and stigma, × 1; *c*, young ovary without style, × 1; *d*, spathaceous calyx, spread, × ½.

Spaniards. This is supported by the fact that a species called *hoang souc quei*, by the Chinese, is a native of China where it is cultivated for its flowers and roots. The flowers are used for food, while the roots are used as medicine. A mucilage produced from the plant is used for sizing paper.

The Chinese specimens of lagikway were known to Linnæus in 1753 as *Hibiscus manihot*.[5] Medicus changed this to *Abelmoschus manihot*[6] in 1787. On the other hand, Loureiro[7] classified the plant as the common okra [*Abelmoscus esculentus* (Linn.) Moench]. Merrill,[8] repeating Loureiro's error, referred to it as the same plant. Obviously, these references have not led to the correct identification of lagikway. The following description of the plant with its nomenclature and synonyms[9] is given for the proper identification of the species.

ABELMOSCHUS MANIHOT (Linn.) Medic. subsp. MANIHOT fo. SPECULATUS (Bakh.) Borss.*

Abelmoschus manihot (Linn.) MEDICUS, Malv. (1787) 46; Ulbrich in LOES, Beih. Bot. Centralbl. (2) 37 (1919) 156 (Prodr. Fl. Tsingtau); S. Y. HU, Journ. West China Bord. Res. Soc. 15B (1945) 136; HARA, Enum. Spermat. Jap. 3 (1954) 145; HU, Flora of China, Malv. (1955) 35–36.

Hibiscus manihot LINN., Sp. Pl. (1753) 696; CAVAN., Diss. 3 (1787) 172, Plate 63, fig. 2; Sims, Bot. Mag. 41 (1815) 41, Plate 1702; LIU, Bull. Peking Soc. Nat. Hist. (3) 2 (1928) 132; HSIA, Contr. Inst. Bot. Nat. Acad. Peiping 1 (1931) 58; HAND–MAZZ., Symb. Sin. 7 (1933) 610, Beih. Bot. Centralbl. 52 (1934) 164; KIA, Pl. Sin. Ill. (1937) 435, fig. 739.

Hibiscus palmatus CAVAN., Diss. 3 (1787) 168, Plate 63, fig. 1.

Hibiscus esculentus sensu LOUR., Fl. Cochinch. (1790) 421, *non* Linn.

Hibiscus manihot var. *palmatus* DC., Prodr. 1 (1824) 448; HAND.–MAZZ., Symb. Sin. 7 (1933) 610.

Hibiscus japonicus MIQ., Ann. Mus. Lugd. Mat. 3 (1867) 19.

Hibiscus manihot Linn. var. *typicus* HOCHR., Ann. Cons. Bot. Geneve 4 (1900) 154.

Abelmoschus esculentus sensu MERR., Trans. Amer. Philos. Soc. *n.s* 24 (1935) 261, *non* Moench.

[5] Species Plantarum (1753) 696.

[6] Malv. (1787).

[7] Flora Cochinchinensis (1790) 421, *non* Linn.

[8] Trans. Amer. Philos. Soc. *n.s.* 24 (1935) 261, *non* Moench.

[9] Shiu-ling Hu in Flora of China, Malv. (1955) 35–36 gave these synonyms for *Abelmoschus manihot* (Linn.) Medicus.

* This nomenclature was furnished the Philippine National Herbarium by Jan van Borssum Waalkes of the Rijksherbarium, Leiden, Holland.

Local names unregistered: *Lagikway* (Tagalog); *likway* (Cebu Bisaya); *lagikway baniwayon, lagikway malaguhon* (Hanunnóo); *glikway lakwis, glikway glumawag,* and *glikway gikug gued* (Sabanon).

A shrub 2 to 3 m tall, the twigs rounded, 3 to 5 mm in diameter, green and glabrous. Leaves simple, alternate, glabrous, palmately 3 to 5 lobes sometimes indistinctly lobed, petioles rounded, 6 to 13 cm long, 2 to 3 mm in diameter, chartaceous when dry, sinuses broad or narrow, lobes linearly lanceolate, nearly entire, gradually pointed towards the apex, the central lobe 6 to 15 cm long, 1.5 to 2 cm wide, other lobes gradually shorter and smaller, the last lobe smallest and shortest. Flower solitary, axillary, often terminal, sub-racemose 1 to 3 flowered; peduncle rigidly hirsute, 7 cm long, 3 mm in diameter; bracts 4 to 5, 3 to 4 cm long, 5 to 10 mm wide at the base, acute, persistent, hair pilose at the margins, calyx spathaceous, 3 cm long or a little shorter than the bracts, tomentous in and out, split down one side, 12-nerved, 3- to 5-toothed at the apex often indistinct, deciduous; corolla yellow with a dark purple center, petals broad, obovately rounded, 7 to 8 cm long, 4 to 5 cm wide; stamens numerous, yellow, sub-sessile along the staminal tube, staminal tube 5-toothed at the apex; ovary globular, 4 to 5 loculed, ovules numerous in each compartment, placentation axillary; style as long as the staminal tube or a little longer, stigma 4- to 5-branched, spatulate-discoid, each branched 4 to 5 mm long, hairy. Fruit a dry capsule, hirsute, ovate-ellipsoid, 4 to 5 cm long, 2.5 cm in diameter, shortly-beaked. Seeds small and numerous.

MINDORO: Mt. Yagaw, *Philip. Nat. Herb. 18983 & 37889 Conklin,* cultigen, September 30, 1953 and March 31, 1958, respectively. LUZON: Laguna Province, Los Baños (College of Agriculture) *Philip. Nat. Herb. 22473 Villegas,* cultigen, January 11, 1954; *Philip. Nat. Herb. 22680 Pancho,* cultigen, January 27, 1955. MINDANAO: Zamboanga del Norte Province, Dikus, *Philip. Nat. Herb. 36017, 36018, & 36019 Frake,* cultigen, September 15, 1957.

This plant is closely related to *Hibiscus notho-manihot* F. v. M. except that the latter has white corolla.

Found almost all over the Philippines where the plant is cultivated for its edible leaves. Never found in wild state.

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